DRXTH-TE-CR-82126

AD A115218

ECONOMIC EVALUATION OF MUNITIONS MANUFACTURING PINK WASTEWATER TREATMENT ALTERNATIVES USING A PRESENT VALUE-UNIT COST METHODOLOGY

CONTRACT NO. DAAK70-80-C-0101

BY

V. J. CICCONE & ASSOCIATES, INC.
14045 JEFF DAVIS HIGHWAY
WOODBRIDGE, VA. 22191

FEBRUARY 1982

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

PREPARED FOR

U. S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MD. 21010

AND

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT COMMAND
FORT BELVOIR, VA. 22060

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: DRXTH-TE-CR-82126	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Economic Evaluation of Munitions Manufacturing Pink Wastewater Treatment Alternatives Using a Present Value-Unit Cost Methodology	5. TYPE OF REPORT & PERIOD COVERED: Final Report Jun 1980-31 Nov 1981
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Dr. Vincent J. Ciccone, Mr. Richard P. Schmitt, Dr. James M. Morgan, Jr., Dr. George A. Garrigan	8. CONTRACT OR GRANT NUMBER(s): DAAK70-80-C-0101
9. PERFORMING ORGANIZATION NAME AND ADDRESS: V. J. Ciccone & Associates, Inc. 14045 Jefferson Davis Hwy. Woodbridge, VA 22191	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62720A, 1L162720D048, EW, W-47
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Toxic and Hazardous Materials Agency, Aberdeen Proving Grd, MD 21010	12. REPORT DATE: February 1982
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office): US Army Mobility Equipment Research and Development Command Ft Belvoir, VA 22060	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This project was accomplished as part of the US Army's pollution abatement program D048. The primary objective of this program is to provide through R&D efforts cost-effective techniques, processes and systems to aid in achievement of the Army's goal in environmental protection and enhancement.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Economic Analysis; Present Value-Unit Cost; Pink Water; Munitions Manufacturing Wastewaters; Economic Models; Activated Carbon; UV-Ozone; Ultrafiltration; Liquid/Liquid Extraction; Powdered Carbon; Surfactant Complexing; Water Reuse; TNT/RDX Wastes; Munitions

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This economic evaluation studies munitions manufacturing wastewater (pink water) treatment alternatives using computer simulations based on a present value-unit cost (PVUC) methodology and compares seven state-of-the-art processes: activated granular carbon adsorption with and without carbon regeneration; ultraviolet-ozone; ultrafiltration; liquid/liquid extraction; powdered carbon adsorption; and surfactant complexing. Preliminary designs for 100,000 gallons per day and 1,000,000 gallons per day treatment facilities were prepared, based on pilot- and laboratory-scale data available; cost,

cont.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. KEY WORDS

Capital Costs
O&M Costs
Water Reclamation
Pink Water Pollution Abatement Technology
Pollution Abatement

20. ABSTRACT

cont

estimates were developed for the full-scale facilities and the resulting unit treatment costs for a 30-year time frame. Cost sensitivity analyses were made of selected significant factors, e.g., carbon regeneration vs no regeneration; density of ultraviolet lamps; surfactant dosages; and, powdered carbon vs the exchange rate of carbon. The several advanced wastewater treatment methods are listed in order of preference based on the PVUC treatment cost per 1,000 gallons of pink water treated. The single most cost effective alternative is activated granular carbon adsorption technique with on-site thermal regeneration of the carbon.

A glossary of selected terms is provided.

DRXTH-TE-CR-82126

ECONOMIC EVALUATION OF MUNITIONS MANUFACTURING PINK WASTEWATER TREATMENT ALTERNATIVES USING A PRESENT VALUE-UNIT COST METHODOLOGY

CONTRACT NO. DAAK70-80-C-0101

BY

V. J. CICCONE & ASSOCIATES, INC.
14045 JEFF DAVIS HIGHWAY
WOODBRIDGE, VA 22191

FEBRUARY 1982

Approved for public release;
Distribution unlimited

PREPARED FOR

U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MD 21010

and

U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND
FORT BELVOIR, VA 22060

EXECUTIVE SUMMARY

Seven feasible alternative Pink Water treatment systems were evaluated economically using the Present Value-Unit Cost (PVUC) methodology. This methodology allows treatment unit costs to be calculated on a "systems" basis thereby accounting for all of the major system unit processes and components. Preliminary designs for daily flows of 10^5 and 10^6 gallons per day (GPD) were prepared to include flow diagrams and data sheets for each alternative treatment system. The design basis provides that the plant effluent would contain less than 1 mg/l TNT.

Capital and operating costs were obtained from published and unpublished sources (e.g., from an equipment manufacturer or supplier), adjusted if necessary to reflect 1980 dollars, and converted to functions suitable for use in the computerized PVUC model.

Computer simulations which compared the seven alternatives in various combinations with each other were conducted. The results were tabulated to yield a relative ranking of the feasible alternatives on the basis of the PVUC values. The following ranking was obtained:

a) granular carbon with thermal regeneration;
b) granular carbon with no regeneration;
c) surfactant complexing; powdered carbon with atomized suspension technique (AST) regeneration;
d) ultraviolet-ozone;
e) liquid/liquid extraction;
f) ultrafiltration.

Analytical (i.e., mathematical) experiments were conducted which examined the "sensitivity" of the PVUC model decision parameters to variations in selected significant factors, such as the adsorption rate for carbon (lbs of TNT/lb of carbon). The graphs show the calculated model response due to the variations.

The major conclusions reached in this study are:

a) the most promising of the seven alternatives studied is Granular Carbon with Thermal Regeneration;
b) the least promising is Ultrafiltration;
c) the best documented alternative is Granular Carbon;
d) one of the least documented is Surfactant Complexing.

Recommendations are to:

a) concentrate research efforts on improving the efficiency of those unit processes identified in the Granular Carbon with Thermal Regeneration alternative;
b) focus these efforts on those processes concerned with regeneration of the carbon;
c) continue research on the Surfactant Complexing alternative to identify a more efficient complexing agent free of either mutagenic or carcinogenic characteristics;
d) conduct research to document the performance characteristics of surfactant complexed sludge concentration dewatering and ultimate disposal.

The authors wish to express their sincerest thanks by acknowledging the valuable and timely comments, guidance and contributions made by Mr. J. Klein (USATHAMA), Mrs. E. Radoski (USAMERADCOM), Mr. B. Jackson (LCWSL), and the engineers and scientists from numerous other Army agencies who provided technical inputs and information. Special thanks are also given to the many members of the VJCA staff who were all instrumental in the performance of this study and the preparation of this report.

TABLE OF CONTENTS

TABLE OF CONTENTS (CON'T)

TABLE OF CONTENTS (CON'T)

TABLE OF CONTENTS (CON'T)

TABLE OF CONTENTS (CON'T)

COMPUTER OUTPUTS

1.0 INTRODUCTION

1.1 BACKGROUND

1.1.1 The Department of Defense is responsible for a number of operations engaged in the manufacture and loading of explosives and/or propellants. The ammunition manufacturing and loading facilities are mostly Government-Owned, Contractor Operated (GOCO). The prime contractor for each facility is usually a major U.S. corporation retained for a specific number of years, and the contractor is responsible for all business and industrial operations, to include environmental pollution abatement activities. This study deals with the evaluation of seven alternative treatment systems designed to control pink wastewater discharges from such ammunition manufacturing and loading plants.

1.1.2 The United States Army controls seventeen Army Ammunition Plants (AAP) engaged in explosive or propellant manufacture. Seven AAP's engage only in manufacturing activities, eight are involved only in Load, Assemble and Pack (LAP) activities and two engage both in manufacture and LAP activities. The Army manufactures all explosives (except nitroglycerin) employed by the United States Air Force and the Army LAP facilities process Air Force munitions. The Air Force controls only one munition manufacturing plant but it is not concerned with pink wastewater problems at this time. The United States Navy controls and operates six munition manufacturing installations, four of which have pink wastewater effluent discharges. The service installations with potential pink wastewater problems are shown in Table 1.1.1.

1.1.3 Some of the mentioned munition facilities are relatively modern while others are of older vintage. A comprehensive effort has been underway in the Department of Defense to modernize munition production and loading plants. The modernization effort includes the abatement of pollution discharges which have an adverse impact on the environment and on local or regional streams and rivers. Stringent federal and state regulations require that munition facility discharges meet exacting requirements. As treatment of wastewaters from such military explosive and propellant production facilities is complex and expensive, efficient management of in-plant production methods and industrial

Table 1.1.1

U.S. Army and U.S. Navy Ammunition Facilities Capable of Generating Pink Wastewater

Army Ammunition Plants (AAP)	Navy Ammunition Depots (NAD) or Navy Weapons Stations (NWS)
Hawthorne - Hawthorne, NV*	Crane - Crane, IN
Holston - Kingsport, TN	Yorktown - Yorktown, VA
Iowa - Burlington, IA	
Joliet - Joliet, IL	
Kansas - Parsons, KS	
Lone Star - Texarkana, TX	
Louisiana - Shreveport, LA	
McAlester - McAlester, OK*	
Milan - Milan, TN	
Newport - Newport, IN	
Radford - Radford, VA	
Volunteer - Chattanooga, TN	

*Navy Plants now operated by the U.S. Army.

housekeeping require increasingly efficient pollution control methods. Advanced wastewater treatment technology is being planned and, in certain locations, already employed in the military explosive and propellant industry to assure that the wastewater treatment plant effluents and the discharged pollutants will meet strict effluent controls.

1.1.4 The abatement of pollution is one of the major and integral parts of the munitions industry modernization program. Implementation of the program is being aggressively pursued and has gone beyond the initial stages at selected installations. Extensive research and development studies have already been undertaken throughout the munition industry to insure reduction in the discharge of key pollution components in the various waste streams. Industry-wide effects are now being felt in a continuing pollution abatement program, in the promise

of new advanced wastewater treatment technologies, and in the implementation phase which promises efficient and economically operated wastewater treatment facilities.

1.1.5 Pollution abatement of one such wastewater, known throughout the industry as "pink water", is the specific subject of this study. The pink wastewater effluent contains trinitrotoluene (TNT) nitrobodies in suspension and solution at varying concentration levels.

1.2 TECHNICAL APPROACH

1.2.1 By applying the Present Value-Unit Cost (PVUC) method, this study evaluates the relative economic advantages of seven different protocols used to remove TNT constituents from wastewaters of the explosive manufacturing and certain LAP operations. The evaluation focuses upon a comparison of the calculated costs of the alternative treatment methods in proposed full-scale treatment facilities with capabilities of 10^5 gallons per day (GPD) and 10^6 GPD.

1.2.2 The PVUC methodology,[7] a computerized mathematical model approach, evaluates the cost differentials of the seven alternative pink wastewater treatment system designs. The calculated outputs, presented in both the tabulated and graphical formats, provide military planners, engineers and decision-makers with information for making effective and economically efficient wastewater treatment decisions.

1.3 OBJECTIVES

1.3.1 The objectives of this study were to:

a) Review pink wastewater pilot and laboratory operational data.
b) Establish an <u>a priori</u> order of advanced wastewater treatment preferences based upon previous pink wastewater treatment efforts.
c) Obtain capital and operation and maintenance cost data for the proposed full-scale unit processes involved.

d) Analyze cost functions and transform to PVUC format.

e) Conduct in-depth PVUC comparative cost simulations for seven advanced pink wastewater treatment alternatives.

f) Compile cost simulations in both tabular and graphical form.

g) Conduct sensitivity analyses of selected alternatives.

h) Submit monthly reports.

i) Submit a draft report for review and a final report with conclusions and recommendations.

2.0 INVESTIGATION

2.1 LITERATURE SEARCH

2.1.1 An extensive on-line computer literature search focusing on the treatment of pink water was conducted to insure the appropriateness of the techniques to be followed. Descriptive item key-words used in the search were: TNT, trinitrotoluene, pink water, red water, industrial wastes, munitions wastes, munition waste pollution abatement, costs, present value unit costs, and risks. On-line requests were made of (a) Defense Technical Information Center, Cameron Station, Virginia and (b) Dialog Information Retrieval Service, Palo Alto, California. The information retrieval service of the U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland, was queried to seek file information topics and microfiche cards related to TNT, pink water (and red water) as far back as 1950. In addition, copies of pertinent documents were obtained from the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), Aberdeen Proving Ground, Maryland, and from the Large Caliber Weapon Systems Laboratory, U.S. Army Armament Research and Development Command (ARRADCOM), Dover, New Jersey.

2.1.2 Laboratory-scale and pilot-plant scale wastewater treatment experimental data provided by staff and other subordinate elements of ARRADCOM were reviewed.

2.1.3 Munition plants were visited and laboratory-scale and pilot-plant scale treatment processes were observed. Industrial wastewater treatment equipment manufacturer data and a variety of construction data concerning unit processes were compiled to provide capital, operating and other necessary cost information. Full-scale plant-size units to treat 10^5 GPD and 10^6 GPD were designed and plant flow patterns were selected. The PVUC model was written in micro-BASIC language (see Section 2.7) as a convenient method to compare the several treatment alternatives. By employing the foregoing approach, the ability of the PVUC model to analyze waste treatment alternatives was demonstrated and the calculated results obtained were used for sensitivity analyses of selected parameters.

2.1.4 The advantages of the approach selected and followed allowed a logical solution to the problem. The literature search, data review, plant visits, cost data collection, full-scale plant design and PVUC model use were approached on a systematic basis. The main emphasis involved the translation of the experimental data to plant design and thence to PVUC analysis. The PVUC method is simple to use and understand. The entire cost functions across time horizons* can be fully comprehended as the micropricing concept is employed and at the same time the model examines a comparison of alternatives in a macrosense. Conversely, micropricing assists in decision-making in a macrosense, since the PVUC model provides the decision-maker with an overview of the whole system being investigated. When the model is understood and correctly interpreted, results can be easily developed to permit the user to make an immediate decision, to postpone a decision over a planning horizon, or to adjust constantly fluctuating factors.

2.1.5 The main disadvantage is that an assumption must be made that the user, or the decision-maker, is knowledgeable with the concepts of systems analysis and is conversant with interactive modes, in this case micro-computers.

2.2 SITE VISITS

2.2.1 Site visits were made as indicated to the following installations:

a) Iowa Army Ammunition Plant, Burlington, Iowa: December 10-11, 1980.
b) Large Caliber Weapon Systems Laboratory,, U.S. Army Armament Research and Development Command, Dover, New Jersey: October 22, 1980 and January 12, 1981.
c) U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland: July 30, 1980.
d) U.S. Army Natick Research and Development Command, Natick, Massachusetts: February 9, 1981.
e) U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland: July 30, 1980, March 10, 1981 and July 16, 1981.

*Time horizons are periods of one to five years, six to ten years, etc., for a thirty-year period.

2.2.2 On each visit, personnel involved in pink wastewater treatment processes or research activities were interviewed, pilot- and laboratory-scale facilities were visited where appropriate and pertinent data and references were obtained. Site visits were supplemented by correspondence and discussions with knowledgeable personnel at the several installations listed, or at other installations.

2.3 PINK WATER SOURCES AND CHARACTERISTICS

2.3.1 Pink Water Sources

2.3.1.1 The munitions industry as a pink wastewater producer may be characterized by two major activities. First, manufacturing involves the production of an explosive or a propellant or an intermediate product from raw materials; the manufacture of TNT is an example. The second major activity, Load, Assemble and Pack (LAP), involves the loading of an explosive product into a munition and may also involve the blending of various munitions products in the loading process.

2.3.1.2 Pink water is the common name given to the aqueous colored waste which is generated at all (a) trinitrotoluene (TNT) manufacturing plants, (b) at all LAP operations where propellants and explosives are transformed into live munitions, or (c) where TNT-loaded munitions are demilitarized or unloaded. The colored wastewater is a principal effluent from munitions spills and from building and equipment washdown operations. In brief, it is a solution of TNT in water which appears everywhere TNT is made, processed, loaded or unloaded, containing TNT and other nitrobodies.

2.3.1.3 Pink wastewater from manufacturing operations may originate from fog filter effluents such as spent acid recovery (SAR) units; nitration fume scrubber discharges; "red water" distillates*; finishing building hood scrubber

*The TNT purification process involves the use of sellite, a concentrated solution (16 percent) of sodium sulfite (Na_2SO_3). Crude TNT is washed with sellite and the unwanted isomers of TNT react with sunlight or ultraviolet light leaving alpha-TNT. The sellite solution, together with the rinse waters, constitutes the red water.

and washdown effluents; and, possibly, spent acid recovery wastes. The first two types of pink wastewater may contain trinitrotoluene isomers and all three may contain dinitrotoluenes. At LAP installations the pink water generally results from actual unloading operations of defective munitions, demilitarization of munitions, the steaming out of rejected projectiles as well as facility washdown and clean-up activities. Table 2.1.1 summarizes pink water sources.

Table 2.1.1

Munitions Operations Producing Pink Wastewaters

Manufacturing Operations	Load, Assemble, Pack Operations
Stack fog filters	Loading and unloading munitions
Nitration fume scrubbers	Demilitarization of munitions
Red water concentration distillates	Steam out of rejected projectiles
Finishing building hood scrubbers and washdowns	Facility washdown and clean-up
Spent acid recovery operations (SAR)	

2.3.1.4 The characteristic pink color persists throughout dilution practices or treatment until the complex TNT compound is reduced to a concentration of relatively few milligrams per liter. "Pink water" should be differentiated from "red water" which is a highly concentrated sulfonated nitrobody in wastewater that results from purification of TNT.

2.3.2 Pink Water Characteristics

2.3.2.1 Pink wastewaters contain mostly trinitrotoluene, and lesser amounts of other nitro compounds (nitrobodies) such as dinitrotoluene (DNT) and isomers of TNT which may be toxic and hazardous.[37] The term "nitrobodies" include alpha-TNT, other isomers, other sellite process products and by-products from the munitions production process.

2.3.2.2 Large quantities of various wastewaters are generated daily at a number of the production and loading sites. Relatively small quantities of TNT, DNT, cyclotrimethylene-trinitramine (RDX), cyclotetramethylene-tetranitramine (HMX), and other nitrobodies are in the contaminated waste streams. The concentrations of TNT, RDX, and HMX have been identified by both laboratory and field experience as being toxic. Even though DNT has been identified as a potential carcinogen, absolute concentrations of DNT that cause harmful effects have not yet been conclusively identified.

2.3.2.3 TNT is toxic below the levels of visibility of the characteristic pink color in wastewater. While fresh solutions of TNT in water are practically colorless, when TNT dissolves in wastewater and undergoes photolysis by exposure to ultraviolet light, there are formed highly colored, poorly identified chemical compounds which are similar to dyes.

2.3.2.4 The pink color in TNT solutions also may be caused by making the solutions alkaline without exposure to ultraviolet light. Concrete tanks may cause this phenomenon until residual alkaline components have been leached from the tank surfaces. Earthen dikes, or lagoon walls and bottom surfaces, may also contribute alkaline products. The alkaline-imposed color may be reversed by acidification, a phenomenon not noted in the sunlight-induced coloration. Exposure of the TNT solutions simultaneously to both alkaline and sunlight conditions causes the nitrobodies to become highly complex. The complexity and large number of compounds identified in a typical synthetic pink water are listed in Table 2.1.2.

2.3.2.5 TNT exists as 2,4,6-trinitrotoluene (alpha-TNT) $[(NO_2)_3C_6H_2CH_3]$, an aromatic ring compound. Solid TNT exists as pale yellow crystals and has a reported specific gravity of 1.3 to 1.6. It is soluble in water and the extent of the solubility is strongly temperature dependent. At 20^oC the solubility is 160 mg/l. At lower temperatures it is less soluble. A saturated TNT solution cooled below 20^oC will crystallize. When warmed, the crystals will slowly return to solution. As TNT is soluble in water to the extent greater than 100 mg/l at ambient conditions, the exact value depends strongly upon temperature and the presence or absence of other solutes.

Table 2.1.2

Compounds Identified in Synthetic "Pink Water"

Compound	Estimated percentage*	Compound	Estimated percentage*
alpha-TNT	(45%)	2-amino-4,6-dinitrobenzoic acid	5-6%
Trinitrobenzene	0.5-1.0%	2,2'-dicarboxy-3,3',5,5'-tetranitro-azoxybenzene (white compound")	Trace
4,6-dinitroisoanthranil	1.0%	2,2'-dicarboxy-3,3',5,5'-tetranitro-azobenzene ("desoxy white compound")	7%
4,6-dinitroanthranil	3-4%	2-carboxy-3,3',5,5'-tetranitroazoxy-benzene (not confirmed)	- 2%
2,4-trinitrobenzaldehyde (photo sensitive)	8-10%	2-carboxy-3,3'5,5'-tetranitroazo-benzene	- 2.3%
2,4,6-trinitrobenzonitrile	3-4%	2-amino-4,6-dinitrobenzoic acid	- 4-5%
Unknown II (unstable)		Origin material	- 1.2%
2,4,6-trinitrobenzylalcohol*	< 1%	High molecular weight insoluble condensates	- 60%
3,5-dinitrophenol	- 1%		
Unknown III	< 1%		

*Estimated the percent of total TNT photoproduct

Note: Analysis is based on work performed by the Chemistry Research Department of the Naval Weapons Center, Silver Springs, MD.[2,3]

Source: Tatyrek[36]

2.3.2.6 Concentrations of TNT in untreated munition plant or washdown wastewaters generally fall in the 100-200 mg/l range. The concentrations would consist of TNT nitrobodies in both solution and suspension. RDX concentrations in untreated wastewaters generally range from 10-30 mg/l. These concentrations, plus HMX, are reduced in certain wastewater treatment processes which are hereinafter described. In general, reducing pink water concentrations from approximately 120 mg/l to 10 mg/l presents no major difficulty in envisioned full-scale treatment facilities. Reducing the discharge concentrations under full-scale conditions to 1 mg/l can be done with careful control and treatment. Reducing plant effluents to extremely low concentrations may not be met in any single treatment system herein described. It may be possible to meet this lower limit by additional units or by combining treatment methods in systems collectively using the best available technology. The Hazardous Waste and Consolidated Permit Regulations which appeared in the Federal Register, 45 FR 33123, Monday, 19 May 1980,[38] 40 CFR Part 261, as amended by 46 FR 56582-56589,[39] Tuesday, November 17, 1981, listed hazardous waste from specific sources. One of the specific sources was Explosives. The U.S. Environmental Protection Agency (EPA) hazardous waste number K045 was indicated as "spent carbon from treatment of wastewater containing explosives" and K047 as "pink/red water from TNT operations." According to the Hazards Code both the K045 and the K047 waste was classified as reactive waste. No concentration discharge limit was placed on either reactive waste.

2.3.2.7 Other major pollutants from TNT production include nitrates, sulfates, sodium sulfite, sodium nitrate, sodium biosulfite, sodium sulfide, sodium thiosulfate and sodium trinitromethane sulfonate but were not the subjects of this study.

2.4 PINK WATER TREATMENT METHODS

2.4.1 The disposal of TNT in an environmentally acceptable manner poses serious difficulties. To do so effectively requires employment of advanced wastewater treatment methods to remove both suspended and dissolved concentrations.

2.4.2 The treatment goal for pink water includes the most reliable and economical concentration process or destruction method capable of treating relatively large quantities of wastewaters with relatively low or no concentrations of pollutants observed in plant effluents. Concentration of the pink water contaminants to a form which may be totally destroyed is the ultimate goal. This goal may ultimately be reached by employing advanced wastewater treatment processes singly or in combination. To reach anticipated low effluent values will require some refinements in the current state-of-the art treatment processes and a combination of alternative systems may be necessary to accomplish these goals economically.

2.4.3 Tatyrek[36] described the current state-of-the-art for the then (1976) promising treatment methods for TNT munitions wastewaters. The report detailed the work accomplished under the technical direction of the Modernization and Special Technology Division of the Manufacturing Technology Directorate of Picatinny Arsenal, the predecessor of Large Caliber Weapon Systems Laboratory. The report also included work on pink water studies which had previously been initiated by other government and private organizations. The fourteen methods of pink water treatment which had been studied by 1976 were classified under the general headings of (a) concentration methods and (b) destruction methods. These are listed in Table 2.1.3.

Table 2.1.3

Pink Water Treatment Methods

Concentration Methods	Destruction Methods
1. Distillation	9. Ozonolysis
2. Reverse osmosis	10. Ozonolysis/ultraviolet
3. Carbon adsorption & regeneration	11. Gamma radiation
4. Polymeric adsorption & regeneration	12. Incineration
5. Liquid membrane separation	13. Aqueous phase-catalytic oxide
6. Foam separation	14. Composting and soil disposal
7. Solvent extraction	
8. Water recycle (a conservation method)	

Source: Tatyrek[36]

2.4.4 Some promising methods of treating pink waters have received more attention than others. This study has investigated cost comparisons by the alternative selection scheme made possible by applying the Present Value-Unit Cost Methodology to those promising methods identified by USATHAMA (including two n... listed in Table 2.1.3, i.e., surfactant complexing and ultrafiltration). Design criteria for the major treatment components for full-scale plants were determined based on laboratory and pilot-plant data when available. Otherwise conventional design criteria obtained from established sources were used. The first facility size envisions a treatment plant of 10^5 GPD capacity and the second is a treatment plant of 10^6 GPD capacity. Preliminary designs for full-scale plants of both capacities for the treatment methods selected for comparison are listed in Table 2.1.4.

Table 2.1.4

Full-Scale
10^5 and 10^6 GPD Plant Designs

Concentration Methods	Destruction Method
1. Granular carbon adsorption with/without thermal regeneration	6. Ultraviolet - Ozone
2. Powdered carbon with Atomized Suspension Technique carbon regeneration	
3. Ultrafiltraiton	
4. Liquid/liquid extraction	
5. Surfactant complexing	

2.4.5 The full-scale designs were based on the most complete and comprehensive data available from laboratory-scale and pilot-plant scale studies. Data from some studies were not as complete as originally intended at the beginning of this investigation; this turn of events was caused by the unavailability of data not yet collected or collated and by the fact that research projects underway were delayed. The available specific research data were analyzed to obtain mean values of pink water concentrations prior to and following treatment.

2.4.6 The feasible alternative treatment methods listed in Table 2.1.4 were selected for analysis for the following reasons: granular carbon adsorption is already being employed on a 10^4 GPD pilot-scale and it is a proven TNT concentration method. The pilot-scale results are available only for a non-regeneration process. An on-site pilot-plant AST program for powdered carbon regeneration is currently underway. The powdered carbon adsorption technique, although not yet on a pilot-plant scale basis, appears to have good adaptability to pink water treatment. Ultrafiltration treatment is undergoing laboratory investigation and, although the low molecular weight of the TNT waste product may be difficult to reject with ultrafiltration membranes, an economic comparison appears warranted. Liquid/liquid extraction, listed in Table 2.1.3 as solvent extraction, employs toluene countercurrent with the pink wastewaters followed by white-oil countercurrent with the toluene/TNT and has been found to be a practical and efficient method for treatment on a laboratory-scale experimentation and therefore should be compared economically with the other methods. Surfactant complexing, originally conceived and listed in Table 2.1.3 as a foam separation method, appears to enhance the rate of decomposition of the TNT product. The enhanced decomposition process takes place in the presence of surfactants and alkali, rather than in the presence of alkali alone. Ozonolysis alone does not completely destroy the pink water pollutant contaminants; however, ozonolysis in combination with ultraviolet irradiation appears to have excellent potential as a method for destroying the pink water nitrobodies.

2.5 PRELIMINARY DESIGN CONSIDERATIONS

2.5.1 When this study was originally conceived, it was contemplated that the on-going pink water treatment technology research phase schedules would provide completed design criteria and performance characteristics of the treatment methods to be analyzed (except for ultrafiltration). For various reasons, several of the research and development program reports were not completed. Hence it was necessary to prepare preliminary designs of full-scale (10^5 GPD and 10^6 GPD) plants on the basis of preliminary data as it became available. The decision to proceed in this mode was obtained from the Contracting Officer's Technical Representative.

2.5.2 In preparing the preliminary designs, best available technology methods were incorporated. Manufacturers of specialized equipment furnished cost and operational data. For standardized equipment, operational data were obtained from conventional sources and cost information was sought from sources explained in Section 2.8, Cost Adjusting Data for Price Level Changes.

2.5.3 In the design, the following assumptions were made based upon extensive review of the literature shown in Section 6.0.

a) The average dissolved TNT pink water concentration would vary between 100 and 150 mg/l (design of specific units were calculated on the basis of a TNT concentration in the range of 100 mg/l to 120 mg/l).
b) The average suspended TNT concentrations would be approximately 80 mg/l.
c) The ratio of TNT to RDX would be 70 percent to 30 percent.
d) The solubilities of chemical constituents at ambient temperatures would be:

    130 mg/l for TNT
    50 mg/l for RDX
    5 mg/l for HMX

    (actual dissolved concentrations may be quite different from these limits due to the presence of other organics, alcohols and acids in the constantly varying wastewater streams).
e) Each designed wastewater treatment alternative would receive raw wastewater and reduce same to a finished treatment product as follows:

	Raw	Finished
TNT:	100-120 mg/l	< 1.0 mg/l
RDX:	30-40 mg/l	< 1.0 mg/l
DNT:	Unknown	< 1.0 mg/l

2.5.4 It was not assumed that the treatment alternatives would be sufficiently effective to reduce the wastewater treatment plant effluents to the extremely low concentrations mentioned in Section 2.3.2.6.

2.5.5 The following standardized units were used for design flow:

10^5 GPD = 0.1 MGD = 69.4 gpm (70.0 gpm)
10^6 GPD = 1.0 MGD = 694 gpm (700 gpm)
1,000 gal = K-GAL

2.6 FULL-SCALE PLANT PRELIMINARY DESIGNS AND PROCESS DESCRIPTIONS

2.6.1 On the basis of the available published research, pilot-scale and other data, treatment unit processes were selected and a preliminary full-scale design for each pink water treatment system was made. System flow diagrams are shown for the seven treatment methods on Figures A-1 through A-6 in Appendix A (the flow diagrams for granular carbon with and without regeneration are both shown on Figure A-1). Design data sheets with PVUC catalog numbers, major treatment components and pertinent design data for the 10^5 GPD systems will be found on Tables A-1a through A-6a and for the 10^6 GPD systems, on Tables 1b through 6b, also in Appendix A. Therefore, by jointly considering the flow diagrams (Figures A-1 through A-6), PVUC Catalog Numbers, and Tables A-1a, 1b through A-6a, 6b with Computer Output Sheets, it is possible to study each treatment system in specific detail. To arrive at the system of analysis it was necessary to accept the most up-to-date available research and equipment data for the preliminary design criteria. Otherwise conventional design criteria obtained from established sources were used. From the data search the Granular Carbon Adsorption without Regeneration treatment method appeared to be the best documented and the Surfactant Complexing treatment method the least documented.

2.6.2 In all of the descriptions which follow, the 10^5 GPD plant size is described. The flows can be followed on the appropriate figures and detailed dimensions can be found on the accompanying tables. Flow patterns for the 10^6 GPD plant size are similar to the 10^5 GPD descriptions and, of course,

dimensions and the number of individual units may change because of the order of magnitude increase. For each of the alternatives considered the design basis provides that the plant effluents would contain less than 1 mg/l TNT. In addition, wherever possible, "standardized" units such as tanks or pumps were used throughout the designs and subsequent economic evaluations.

2.6.2.1 GRANULAR CARBON WITH AND WITHOUT REGENERATION: Of all the processes employed for the removal of organic materials from wastewater, activated carbon has the longest history and is the best developed method in use today. Therefore, the process is well documented throughout the industrial and municipal wastewater treatment literature. Activated carbon is also effective in removing some inorganics from wastewater, particularly at the trace levels of certain metals. The process proceeds by adsorption or the attraction and accumulation of one substance on the surface of another. The decision whether to regenerate and reuse granular carbon or to use granular carbon without regeneration is based upon cost incentive. The granular carbon treatment techniques have been designed in this study both with and without thermal regeneration. During the study, a visit was made to the Iowa Army Ammunition Plant, Burlington, Iowa,(19) to observe the operation of a granular carbon treatment process without regeneration. As the granular carbon with thermal regeneration process has been determined to be the most economical of all treatment systems studied, the design of that system will be discussed.

In the design for the 10^5 GPD granular carbon with thermal regeneration process, the assumptions were that influents to the pink water treatment plant would be collected in a subsurface sump. Intermittently, contents of the sump are pumped to a one-day retention equalization tank. Constant flow from the equalization tank would be pumped to a diatomaceous earth filter and from there to a bank of three carbon columns in series, each with a detention time of 35 minutes. As the adsorption capacity of the carbon in a column is exhausted the carbon would be discharged and held in carbon waste tanks, each with a capacity of one carbon column. The liquid discharge, always from the third column operating in series (accomplished by appropriate piping arrangement), would flow to a 25,000 gallon holding tank. If appropriate the liquid plant discharge could be effected at this point and discharged as plant effluent. Some of the

liquid waste could be used again at the diatomaceous earth filter units for backwash operations. Any excess liquid accumulating in the waste carbon tanks could likewise be returned to the equalization tank. The plant has the capability for virgin carbon storage of a minimum of two carbon column capacity. The virgin carbon for make-up purposes is fed, as needed, into the carbon columns through a pipe mixer with water pumped from the holding tank.

In the thermal regeneration scheme, the spent granular material from the carbon waste tanks is conveyed into a multi-hearth furnace, part of the regeneration system, with a thirty-minute retention time. Off-gases would be scrubbed as shown as a part of the regeneration scheme. Regenerated carbon enters a quench tank as part of the cooling process and is stored in a carbon de-fine tank. The regenerated carbon is reintroduced hydraulically into the three carbon column series bank as required. For a non-regenerative granular carbon treatment process, the regeneration scheme would be omitted and the remaining liquid flow patterns would be the same. Spent, unregenerated carbon, used on a once-through basis, must be ultimately disposed of by some acceptable technique. In this study the disposal method considered was "open burning". (See Appendix C, where the O&M cost function for carbon column-granular includes the cost of open burning).

2.6.2.2 UV-OZONE: Oxidation has long been used as a common method of chemically treating water and wastewater. Ozone has likewise been recognized as a powerful chemical oxidant. An oxidizer combined with short wavelength ultraviolet (UV) light has been shown by Farrell et al.[10] and others[1,3,6] to be a promising pink water abatement process. The Farrell process, herein referred to as UV-Ozone, employs banks of ultraviolet lamps around which ozonated pink wastewaters are channeled to flow. Critical design considerations for proper performance include lamp spacing and ozone concentrations.

In the design for the 10^5 GPD UV-Ozone plant, which mainly follows the Farrell et al.[10] investigation, the assumptions were that the pink wastewater treatment plant influent would enter through a sump into a one-day retention equalization tank and then through a diatomaceous earth pressure filter. The filter effluent would enter an ozone precontactor, a counter current flow tank similar to a bubble-cap plate tower, and subsequently to the ozone reactor. The

reactor is a specially designed tank, composed of a number of stages to assure maximum contact of the UV light and ozonated wastewater. The contact time-intensity is dependent upon the flow-through rate and the number of UV lamps per square foot of ozone reactor surface area. The reactor envisioned is similar to that of an enclosed baffled flocculation tank and has a detention time of two and one-half hours. Any resulting off-gas is re-routed to the precontactor for organic oxidation and then to an ozone destroyer tank or water gas separator, if required.

The ozone reactor may be constructed in units or as a single entity. The total number of required 65-watt ultraviolet lamps, each about 5 feet in length and slightly over 1 inch in diameter, would be 2,304. To provide cool dry air to the ozone generator would necessitate installation of an air chiller. Ozone produced in the generator would flow directly to the ozone reactor where it would mix with the pink water and the mixture subjected to UV light from the banked lamps. Treated pink water effluent from the ozone reactor would flow to a 25,000 gallon detention holding tank, which has a return capability to the diatomaceous earth filter for backwash, or to the plant discharge line.

2.6.2.3 SURFACTANT COMPLEXING: The proposed surfactant treatment process for pink waters was initially conceived as a foam separation technique. Foam separation as a method was abandoned when it was discovered that certain surfactants reacted with TNT to form an insoluble compound which would be more easily removed by filtration than by foaming. The surfactant process has been described by Roth(6) and Okamoto, et al.(28,29). More detailed research on the use of surfactants is currently underway at the Louisiana Army Ammunition Plant. The objective of the bench-scale investigation is to evaluate the process for fixation and removal of explosives and LAP residues from pink waters using a quaternary surfactant. The surfactant is expected to react under alkaline conditions to form and remove by filtration an insoluble complex. The surfactant is likewise expected to remove the colored products from the pink waters.

In the design for the 10^5 GPD surfactant complexing process, the assumptions were that the pink water treatment plant influent would enter through a sump into a one-day retention equalization tank. The surfactant is

first introduced upstream of a mixing pipe which is followed by the introduction of sodium hydroxide in solution directly with the surfactant into primary surfactant mixing tanks in series with a secondary reaction tank. Retention time in the surfactant mixing tanks is one-half to one hour. The liquid overflow from the second surfactant mixing tank is directed to a sulfuric acid neutralization tank with a one hour detention.

Resulting sludge is withdrawn from the bottom of the second surfactant mixing tank and directed to a vacuum filter the size of which has been estimated since it is not exactly known at this time what daily volume of liquid/sludge must be filtered. The filtered liquid phase may be returned to the second surfactant mixing tank or to the sulfuric acid neutralization tank as appropriate. In this design, the ultimate disposal of the resulting sludge has not been specifically determined (or costed) and no dedicated sludge disposal method has been estimated. The ultimate sludge disposal method is therefore shown as a phantom incinerator.

2.6.2.4 LIQUID/LIQUID EXTRACTION: Liquid/liquid countercurrent extraction is a method of transferring a solute from one solvent stream to another. This process, as described by Brown and Jackson,[4] is a two-phase system of mutually immiscible solvents. Initially the solute is associated with only one solvent. On the addition of the second solvent with thorough mixing, an equilibrium is achieved in which the solute is distributed between the two solvents in proportions defined by the respective solubility product constants of each solvent-solute phase. Tash, Layne and Goodfellow[35] have found liquid/liquid extraction of pink water to be a feasible and practical process using toluene as the extractant. The laboratory-scale experimentation permitted reduction of TNT concentration to below 1 mg/l. Based on laboratory analysis and a computer program, the extractor column equipment for a pilot-plant extraction system was made. The full-scale design for 10^5 GPD was developed from the Tash, Layne and Goodfellow work. It is anticipated that any small quantities of toluene remaining in the pink water effluent may be removed by extracting with "white oil" which was the original extractant to be considered but later found to be impractical due to the quantities required to effect significant separation of initial TNT concentrations.

The assumptions for liquid/liquid extraction were that following flow through a sump and a one-day retention in an equalization tank, pink water waste would pass through a diatomaceous earth filter and then in series through two solvent extractor columns each 8 feet in diameter by 15 feet in height with detention time of 85 minutes. The toluene solvent is to be introduced at the column bottom from 500-gallon solvent mix tanks. The toluene/TNT effluent is directed to a distillation unit which also receives the white oil/toluene effluent from the second extractor column. By fractional distillation the toluene and white oil are recovered for recycling. The TNT laden sludge from the distillation process must be disposed of by such methods as incineration. The system allows for the effluent from the second solvent extractor to be collected in a 25,000 gallon holding tank, and then returned to the diatomaceous earth filter for backwash operation. A phantom incinerator is indicated for incineration of sludge following distillation (not costed in this study).

2.6.2.5 ULTRAFILTRATION: Ultrafiltration of liquids is an attractive alternative to the usual chemical or other treatment methods, especially for the removal of suspended materials in aqueous waste streams. Through new membrane technology, it offers the advantages of being a simple hydraulic system without certain inherent operator problems with water chemistry and separation schemes, although system problems can develop. Ultrafiltration is a pressure active physical separation process in which a porous membrane is used to restrict the passage of unwanted material while allowing water and some dissolved matter to pass. Generally tubular or hollow filter modules are employed by banks in equipment connected in series. One type of module is a bundle of hollow polymeric fibers encased in a plastic shell held in place at each end of the element by various epoxy or other compounds. The concept has been to provide maximum membrane area under conditions of minimum space, flow and pressure requirements, while maintaining above average permeation rates. The normal molecular range for ultrafiltration cartridges is from less than 2,000 to more than 80,000 M.W. The molecular weight of TNT, the principal constituent in pink water, is approximately 227. In the design of the proposed 10^5 GPD plant two alternatives were investigated; the batch treatment method and the feed and bleed method of operation. The latter method is herein presented for a flow

rate of 70 gallons per minute, a TNT concentration of 118 mg/l and each ultrafiltration module was assumed to have a membrane area of 26.5 square feet.

The assumptions for ultrafiltration were that following the flow-through sump and a one-day retention equalization tank, the pink waters would pass through a diatomaceous earth filter and thence to a 25,000 gallon holding tank. From the holding tank, the filtered wastewater would pass through a total of ten stages of ultrafiltration modules, each equipped with high capacity recirculation pumps. At each stage there is to be a one percent bleed of concentrated TNT effluent to disposal. It is assumed there will be a constant 10 percent TNT removal per stage with a 25 gallons per square foot per day permeate rate at a constant 30 psig. The recirculation rate per module was estimated to be 20 gallons per minute with a resulting 0.46 gallons of permeate per minute per module. It was estimated 1450 modules would be required with a total pump horsepower requirement of 840 horsepower. Even with the 10 stages it was not likely that the 1 mg/l TNT effluent could be obtained. In addition, the final TNT laden ultrafiltration brine effluent would have to be disposed of by incineration or some other suitable method. Such disposal methods costs were not examined in this study.

2.6.2.6 POWDERED CARBON: Powdered carbon is used in many water and wastewater treatment plants. It has been widely used in industry to remove objectionable organic constituents from liquid wastes. The resulting residues separated from the liquids have been discharged by ponding, by incineration or by burial. The powdered carbon treatment process becomes more attractive where reactivation of the carbon can be successfully implemented; therefore, regeneration of the carbon becomes an important factor in the powdered carbon technique studied. The powdered carbon adsorption technique has been described by Jackson(6) on a pilot-plant experimentation which involves regeneration of the carbon by AST. The AST regeneration process as installed at Iowa Army Ammunition Plant was observed in December 1980.(18)

In the calculations for the 10^5 GPD powdered carbon adsorption technique, a standard industrial treatment design was adopted and the assumptions were that the pink wastewater treatment plant influent would enter through a sump into a one-day retention equalization tank. A polymer and a coagulant would both be

introduced to a flash mix tank with overflow to one of two powdered carbon upflow clarifiers in series, each with a fifty minute detention period. Partially exhausted carbon slurry separated in the second clarifier would be returned as influent to the first clarifier. Solids collected in the first clarifier would be directed to a gravity thickener with a two-hour detention capability. Liquid overflow from the second clarifier would be pumped to a diatomaceous earth filter with the effluent flowing to a 25,000 gallon holding tank. As required, the holding tank contents may be used for filter backwash operations or discharged to the receiving stream. Piping arrangements have been shown to permit thickener effluent returned to the clarifier system with sludge withdrawal directly entering the vacuum filtration process; the vacuum filtered sludge would be trucked to ultimate sludge disposal. In this study, no dedicated sludge disposal system or procedure has been included in the cost estimations.

Should the AST regeneration scheme be feasible, resulting filtered sludge would be transported by screw conveyor to the AST furnace where it would be appropriately heat-treated in a 200-pound per day furnace. The off-gases would be scrubbed and the solids residue directed by screw conveyor to a quench tank for cooling. The regenerated carbon would be reintroduced to the system upstream of the second clarifier at approximately the same point where virgin carbon would be introduced into the system as makeup carbon.

2.7 INTERACTIVE PVUC COMPUTER MODEL

2.7.1 The existing computer model for the PVUC method of evaluating wastewater facilites has evolved from earlier versions by Ciccone[7] and Morgan.[14] As was the case in Morgan, this program is in an interactive format in Micropolis Extended BASIC (Micro-BASIC) and is run on a Vector Graphics Micronet II system.

2.7.2 The program is subdivided into five programs identified as PVUC-PART1, PVUC-PART2, PVUC-PART3, PVUC-PART4, and PVUC-PART5 respectively. Briefly, these programs perform the following functions.

2.7.2.1 PVUC-PART1: Through an interactive mode, PART1 gathers necessary preliminaries, such as operator name, date, titles of both systems associated with the present analysis, interest rate, inflation rate, and projected operational days per year. The title page to the output then is printed and the program automatically chains to PART2.

2.7.2.2 PVUC-PART2: This part of the program is used to introduce the actual design of any two alternative wastewater treatment systems under study. There is an option at the beginning of PART2 for the user to obtain a printout, if desired, of the catalog of units available in memory from which the two alternative treatment systems are to be compared. The user begins by designing the first system. An option exists either to call units from the PVUC equipment catalog by specific number and use the values for each unit stored in memory or to call a unit and modify values (costs, sizes, numbers, etc.) according to the needs of the treatment system being designed. The user may alternate between the above options during the design process.

Once the design for a treatment system is complete, it may be displayed or a hard copy printout may be prepared for examination and revision. Once the first treatment system design is satisfactory the program moves directly into the design of the second treatment system. The procedures and options for designing the second system are identical to those for the first system. On completion of the treatment system design phase, the user may chain to either PART3 or PART4. Once this option is taken, the chaining automatically occurs.

2.7.2.3 PVUC-PART3: If PART3 is elected, the Micronet will automatically provide a printout of the complete design specified by the operator of both wastewater treatment systems to be compared. The printout will include a listing of all pertinent data for each treatment unit as determined previously by the operator. If the hard copy is determined by the computer to be too extensive for one page, a special pagination mode will be automatically activated, and printout will be delayed at the end of each page to allow for readjustments of the paper positioning. At the termination of printing there is an automatic chaining to PART4.

2.7.2.4 PVUC-PART4: Upon entering PART4 the program will designate the flow (GPD) for both alternative treatment systems. The operator chooses which flow is to be designated by selecting the appropriate version of PVUC program entered into the computer. Either program permits the options for a hard copy printout of calculations pertaining to the analysis or a direct advancement to a graphical printout, PART5. Given either option, all pertinent calculations are accomplished at this point before execution of the option. Calculated values are stored in an array with six columns (one for each of six five-year horizons) and twenty horizontal lines (one for each variable type under study). If the printout of the result of the calculations is requested, it is executed in tabular format, on one page, with the option for the operator to interject comments about the study which are felt to be pertinent. Once the table is complete there is an automatic chain to PART5.

2.7.2.5 PVUC-PART5: PART5 automatically adjusts the size of the graph to be produced to fit the the maximum space selected, and then prints the Discriminant (i.e, the normalized difference between the PVUC for "A" and PVUC for "B") curve before the printout of the PVUC curves for each alternative wastewater treatment system. Both curves are printed on one graph. The vertical heights of each graph, with appropriate axis labels and captions are set to display attractively on standard sized (8 1/2 inch by 11 inch) paper.

2.8 COST ADJUSTMENT DATA FOR PRICE LEVEL CHANGES

2.8.1 Capital and Operating Cost Function Adjustments

2.8.1.1 Capital cost data for components (unit processes), were extracted from several sources which had different dollar value bases. In order to adjust all data to a current dollar value base (December 1980), each unit process was reviewed for the nature of its construction and the type of materials used both in construction and operation. Then, an appropriate Producer Price Index (PPI) (formerly the Wholesale Price Index) fitting the nature and type of construction and operation of this process, was used to adjust each point estimate of costs (at different flow rates) for the price changes that occurred between the date of the specific price level of the source data and December 1980. For example,

the data retrieved from an EPA publication had costs as of 1974. Updating these costs necessitated a 66.6 percent upward change in each point estimate to bring values into line with December 1980 price levels. In another case, cost estimates gleaned from an EPA document had been set at January 1977 levels. In this instance, the cost data were adjusted by applying the "PPI by Stage of Processing for Materials and Components for Manufacturing" rather than the PPI for all commodities. This cost adjustment resulted in a 49.2 percent increase in the January 1977 data to bring it to December 1980 levels. Another source had data set at the second quarter 1977 PPI dollar values; each point estimate taken from this set was adjusted by a 41.9 percent increase.

2.8.1.2 In instances where the process involved construction-type activity (e.g., concrete or earthen basins for flow equalization tanks), the PPI for "materials and components for construction" was used.

2.8.1.3 After adjusting Cost data to December 1980 levels, cost functions were calculated for each unit process. Thus, all cost functions have a common dollar valid base of December 1980. A similar procedure for O&M Costs, (labor, power, supplies and chemicals), Construction Costs and Capital Cost Recovery Rates, using appropriate indices was followed in this study.

2.8.2 Cost Adjustment Data

2.8.2.1 The interest rate used in this analysis was selected after considering several different measurements of rates of interest and bond yields in the economy as of mid-year 1981. For example, in July 1981, the Council of Economic Advisor's publication of Economic Indicators shows U.S. security yields ranging from 14.699 percent to 15.15 percent, high-grade municipal bonds at 11.03 percent, corporate AAA bonds at 14.38 percent, prime 6-month commercial paper at 16.09 percent, prime rate charged by banks at 20.5 percent and new home mortgage yields at 14.72 percent. The average rate for these measurements led us to the 15.0 percent interest rate used in these calculations.

2.8.2.2 For the rate of inflation the Council of Economic Adivsor's Economic Indicators shows a 1.2 percent change in the consumer price index in July 1981 over the preceeding month for all items, a 1.6 percent change in housing, and a relatively small 0.4 percent change in energy. After taking into account these and other price changes, including the Producer Price Index, these figures were annualized over a July to July basis resulting in a general inflation rate for computation purposes of 13.0 percent annually.

	Alternative "B" \ Alternative "A"	Granular Carbon w/ Thermal Regen.	Granular Carbon w/ No Regen.	Surfactant Complexing	Powdered Carbon w/ AST Regen.	UV-Ozone	Liquid/Liquid Extraction	Ultrafiltration
1	Granular Carbon w/ Thermal Regen.		●	●	●	●	●	●
2	Granular Carbon w/ No Regen.	●		●	●	●	●	●
3	Surfactant Complexing	●	●		●	●	●	●
4	Powdered Carbon w/ AST Regen.	●	●	●		●	●	●
5	UV-Ozone	●	●	●	●		●	●
6	Liquid/Liquid Extraction	●	●	●	●	●		●
7	Ultrafiltration	●	●	●	●	●	●	

TABLE 3.1

MATRIX OF PINK WATER TREATMENT SYSTEMS COMPARED ON A PVUC BASIS

3.0 FINDINGS AND DISCUSSION

3.1 COMPUTER SIMULATION/OUTPUTS

3.1.1 Table 3.1 presents a convenient comparison of pink water treatment alternatives considered in this study. It shows those combinations of systems that were compared on the PVUC basis. The titles are the same for each of the flows examined, however, the computer outputs are identified as "a" for the 10^5 GPD series and "b" for the 10^6 GPD set.

3.1.2 The full-scale plant designs, the specific individual treatment units of varying sizes and modes and the corresponding capital and O&M costs were used as inputs to the Interactive PVUC Computer Model by means of the Micronet systems to make simulation runs as explained in Section 2.7. The carbon with regeneration alternative was compared with each of the other six pink water treatment methods because this system consistently was shown to be the most economical in terms of unit cost of treatment for flows of both 10^5 and 10^6 GPD. Each comparison consists of two tables and two graphical presentations. The first table lists the alternative treatment system PVUC catalog numbers, the number of units in each system, the capital costs, the O&M costs, unit capacities in gallons, the daily rates of flow through each unit and the estimated life of the unit in years. The second table presents the PVUC analysis and includes specific data, such as total capital costs for each alternative, the ratio of capital costs, interest and inflation rates over the period under consideration, salvage values, and daily flows, and summarizes the Discriminant and the unit treatment costs in \$/K-GAL over the entire time horizon. The first graphical presentation is the Discriminant plot versus time horizon and the second graphical presentation is a dual plot of both alternatives considered and represents unit treatment costs in \$/K-GAL or \$/M-GAL over the time horizons.

3.1.3 By coordinating the full-scale plant designs, the cost data and typical computer simulations/outputs (similar to those which follow in an ascending order of unit treatment costs for daily flows of 10^5 and 10^6 GPD), it has been possible to produce findings upon which this section is based.

Computer* Outputs	Title
3.1.3.1a	Granular Carbon Without Regeneration vs. Granular Carbon With Thermal Regeneration
3.1.3.1b	
3.1.3.2a	Granular Carbon With Thermal Regeneration vs. Surfactant Complexing
3.1.3.2b	
3.1.3.3a	Granular Carbon With Thermal Regeneration vs. Powdered Carbon
3.1.3.3b	
3.1.3.4a	Granular Carbon With Thermal Regeneration vs. UV-Ozone
3.1.3.4b	
3.1.3.5a	Granular Carbon With Thermal Regeneration vs. Liquid/Liquid Extraction
3.1.3.5b	
3.1.3.6a	Granular Carbon With Thermal Regeneration vs. Ultrafiltration
3.1.3.6b	

* a = For 10^5 GPD
b = For 10^6 GPD

COMPUTER OUTPUT 3.1.3.1a

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: NO REGENERATION (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)

FOR FLOW RATE OF 100 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 9, 1981

COMPUTER OUTPUT 3.1.3.1a
LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS
INDICATED OTHERWISE IN THE BODY OF TABLE. FLOW IS
100 000 GPD.

ALTERNATIVE (A)
CARBON: NO REGENERATION (0.652 LBS TNT/LB C)

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI						
9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP						
9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN						
9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION						
9006	2	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE						
9015	2	$ 43865	$ 896	200	50000	30
CARBON COLUMN-GRANULAR						
9013	1	$ 151367	$ 80829	2000	100000	30
WASTE CARBON TNK-STL OR MI						
9014	3	$ 5511	$ 0	12000	1000	30
VIRGIN CARBON STORAGE TANK						
9008	1	$ 7709	$ 0	24000	24000	30
PUMP-PRESS. BACKWASH-D.E.						
9004	1	$ 879	$ 4	1.89[a]	10000	30
CONVEYOR SCREW						
9031	1	$ 4566	$ 1000	1[b]	25[c]	30
HOLDING TANK						
9023	1	$ 7612	$ 0	25000	100000	30

ALTERNATIVE (B)
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI						
9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP						
9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN						
9013	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION						
9006	2	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE						
9015	2	$ 43865	$ 896	200	50000	30
CARBON COLUMN WITH THERMAL REG						
9019	1	$ 151367	$ 7227	2000	100000	30
WASTE CARBON TNK-STL OR MI						
9014	3	$ 5511	$ 0	12000	1000	30
VIRGIN CARBON STORAGE TANK						
9008	1	$ 7709	$ 0	24000	24000	30
PUMP-PRESS. BACKWASH-D.E.						
9004	1	$ 879	$ 4	1.89[a]	10000	30
CONVEYOR SCREW						
9031	1	$ 4566	$ 1000	1[b]	25[c]	30
CARBON DE-FINE TANK						
9040	1	$ 137843	$ 1000	2500	2500	30

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet

```
!HOLDING TANK
! 9023  1  $ 7612  $ 0        25000  190000  30
!
!CARBON REGEN FURNACE
! 9011  1  $ 528487$ 28449  1b      30d      30
!

*****              NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER              *****
**********************************************************************************

STUDY CONDUCTED BY GEORGE A. GARRIGAN                         SEPTEMBER 9 1981
```

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

COMPUTER OUTPUT 3.1.3.1a
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: NO REGENERATION (0.652 LBS TNT/LB C))
WITH TREATMENT B (CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 307750 AND FOR ALTERNATIVE B - $ 974080;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 3.16, INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 100000 GALLONS: SYSTEM B 100000 GALLONS

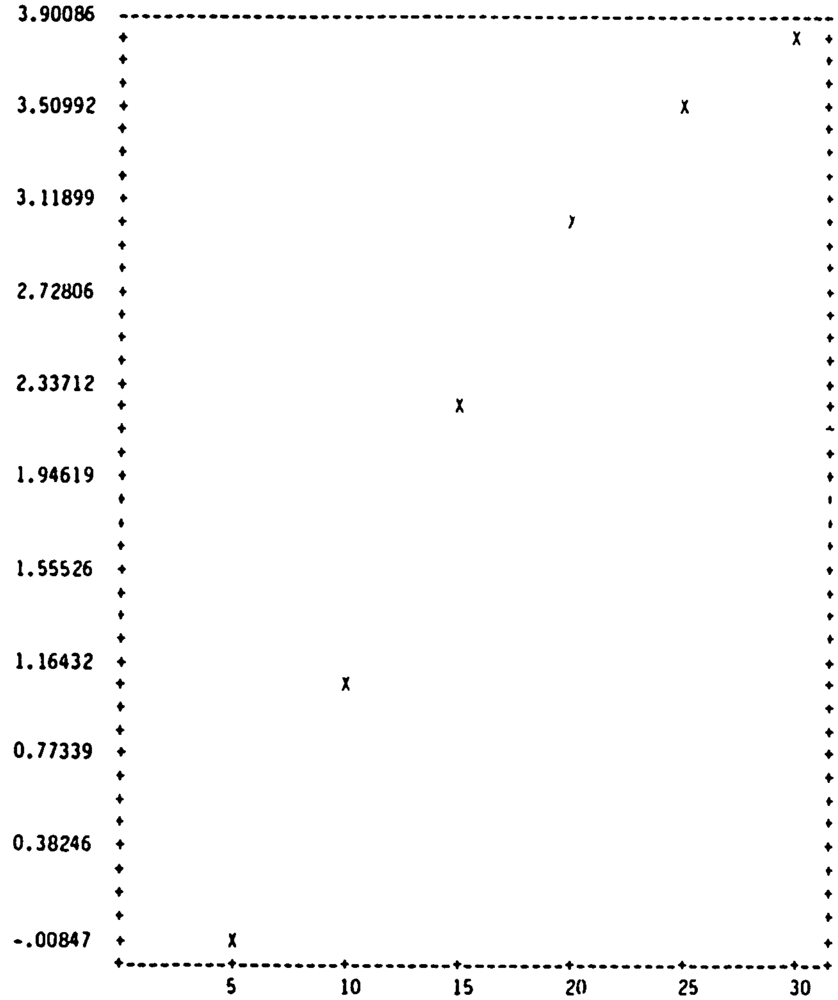
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	444000	1297000	2522000	4090000	5971000	8139000
TOT. OP. COSTS FOR ALTERN. B $	235000	686000	1334000	2164000	3159000	4306000
CURRENT SALVAGE VALUE FOR A $	256000	205000	153000	102000	51000	0
CURRENT SALVAGE VALUE FOR B $	811000	649000	487000	324000	162000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	1.31137	.52158	.19449	.06446	.01602	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	175	350	525	700	875	1050
TOT. FLOW (MGAL) FOR ALTERN B	175	350	525	700	875	1050
RSUM FOR ALTERNATIVE A	2.67500	6.30247	9.15230	11.04570	12.20407	12.87883
RSUM FOR ALTERNATIVE B	1.41526	3.33444	4.84220	5.84394	6.45680	6.81379
*THE DISCRIMINANT IS	-.0083	1.1596	2.2779	3.0806	3.5930	3.8998
PVUC ($/MGAL PROCESSED): A $	2800	2700	2600	2500	2400	2300
PVUC ($/MGAL PROCESSED): B $	2200	2200	2100	2100	2000	2000

****

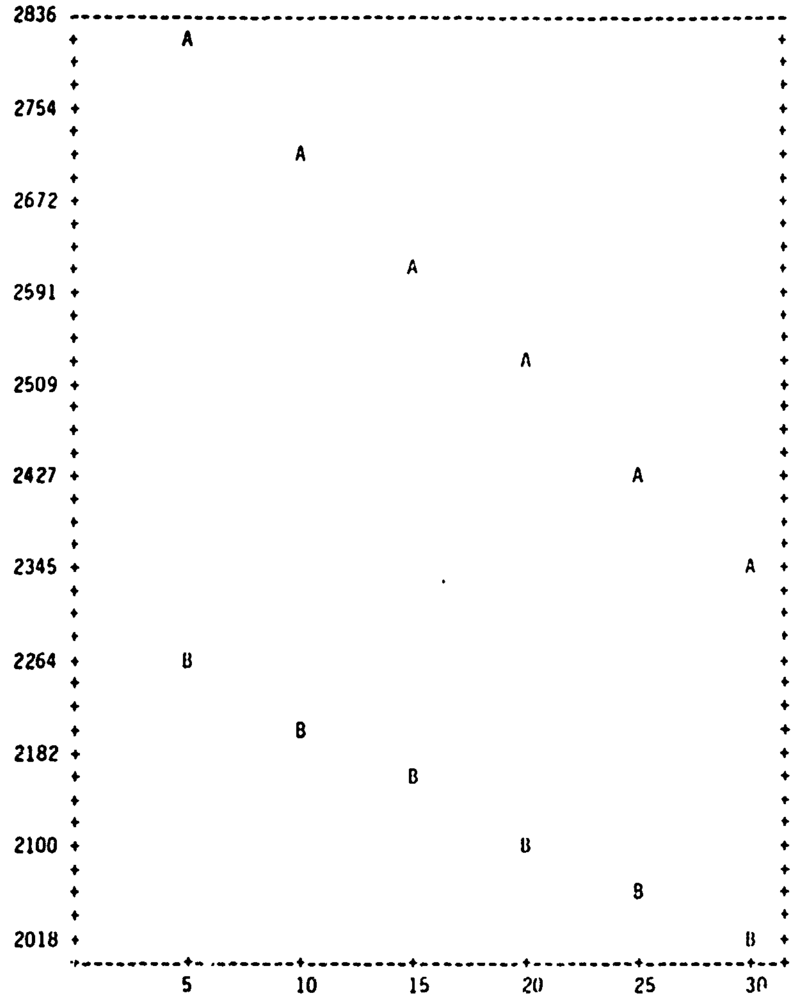
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 9 1981,

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: NO REGENERATION (0.652 LBS TNT/LB C) AND SYSTEM (B):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 9 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: NO REGENERATION (0.652 LBS TNT/LB C) AND SYSTEM (B):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 9 1981

COMPUTER OUTPUT 3.1.3.2a

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): SURFACTANT COMPLEXING

FOR FLOW RATE OF 100 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 10, 1981

COMPUTER OUTPUT 3.1.3.2a
LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMB[illegible] 1980 UNLESS
INDICATED OTHERWISE IN THE BODY [illegible]BLE. FLOW IS
100 000 GPD.

ALTERNATIVE (A)
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)

NAME OF UNIT	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI	9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP	9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN	9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION	9006	2	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE	9015	2	$ 43865	$ 896	200	50000	30
CARBON COLUMN WITH THERMAL REG	9019	1	$ 151367	$ 7227	2000	100000	30
WASTE CARBON TNK-STL OR MI	9014	3	$ 5511	$ 0	12000	1000	30
VIRGIN CARBON STORAGE TANK	9008	1	$ 7709	$ 0	24000	24000	30
PUMP-PRESS. BACKWASH-D.E.	9004	1	$ 879	$ 4	1.89[a]	10000	30
CONVEYOR SCREW	9031	1	$ 4566	$ 1000	1[b]	25[c]	30
CARBON DE-FINE TANK	9040	1	$ 137843	$ 1000	2500	2500	30

ALTERNATIVE (B)
SURFACTANT COMPLEXING

NAME OF UNIT	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI	9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP	9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN	9018	1	$ 18777	$ 0	[illegible]	25000	30
PUMP-PRESS. EQUALIZATION	9006	5	$ 1047	$ 1737	[illegible]	100000	30
SURF. STR/MIX/BODY FEED TNK	9024	1	$ 1361	$ 0	500	0[b]	30
CHEMICAL FEEDER	9025	1	$ 3000	$ 1000	1[b]	1[b]	30
SURF. STR/MIX/BODY FEED TNK	9024	1	$ 1361	$ 0	500	0[b]	30
CHEMICAL FEEDER	9025	1	$ 3000	$ 1000	1[b]	1[b]	30
SURFACT REACT TANK	9035	2	$ 5749	$ 23000	5000	100000	30
VACUUM FILTER POWDERED CARB.	9034	1	$ 73622	$ 1855	1[b]	20[d]	30
SURF. STR/MIX/BODY FEED TNK	9024	1	$ 1361	$ 0	500	0[b]	30

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

HOLDING TANK								CHEMICAL FEEDER							
9023	1	$ 7612	$ 0	25000	100000	30		9025	1	$ 3000	$ 1000	1^b	1^b	30	
CARBON REGEN FURNACE								NEUTRALIZATION TANK							
9011	1	$ 528487	$ 28449	1^b	30^d	30		9022	1	$ 3749	$ 80750	5000	100000	30	

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

****

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

NOTE: Not all values shown relate to column headings,

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

COMPUTER OUTPUT 3.1.3.2a
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C))
WITH TREATMENT B (SURFACTANT COMPLEXING).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 974080 AND FOR ALTERNATIVE B = $ 136445;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = .14 INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 100000 GALLONS: SYSTEM B 100000 GALLONS

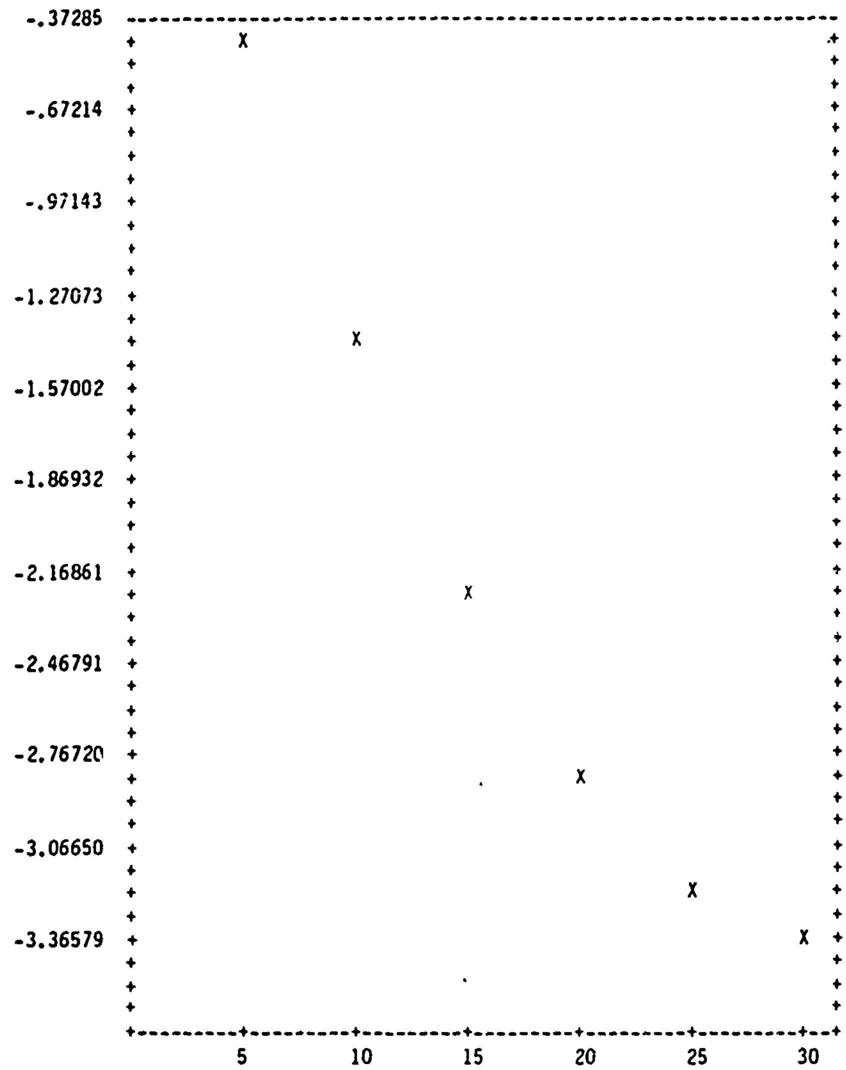
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	235000	686000	1334000	2164000	3159000	4306000
TOT. OP. COSTS FOR ALTERN. B $	697000	2033000	3954000	6411000	9359000	12756000
CURRENT SALVAGE VALUE FOR A $	811000	649000	487000	324000	162000	0
CURRENT SALVAGE VALUE FOR B $	113000	90000	68000	45000	22000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	.05803	.02308	.00860	.00285	.00070	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	175	350	525	700	875	1050
TOT. FLOW (MGAL) FOR ALTERN B	175	350	525	700	875	1050
RSUM FOR ALTERNATIVE A	0.44713	1.05348	1.52984	1.84633	2.03995	2.15274
RSUM FOR ALTERNATIVE B	1.32463	3.12091	4.53212	5.46972	6.04333	6.37746
*THE DISCRIMINANT IS	-.3738	-1.3492	-2.1952	-2.7809	-3.1478	-3.3647
PVUC ($/MGAL PROCESSED): A $	2200	2200	2100	2100	2000	2000
PVUC ($/MGAL PROCESSED): B $	4100	3900	3700	3600	3400	3300

****

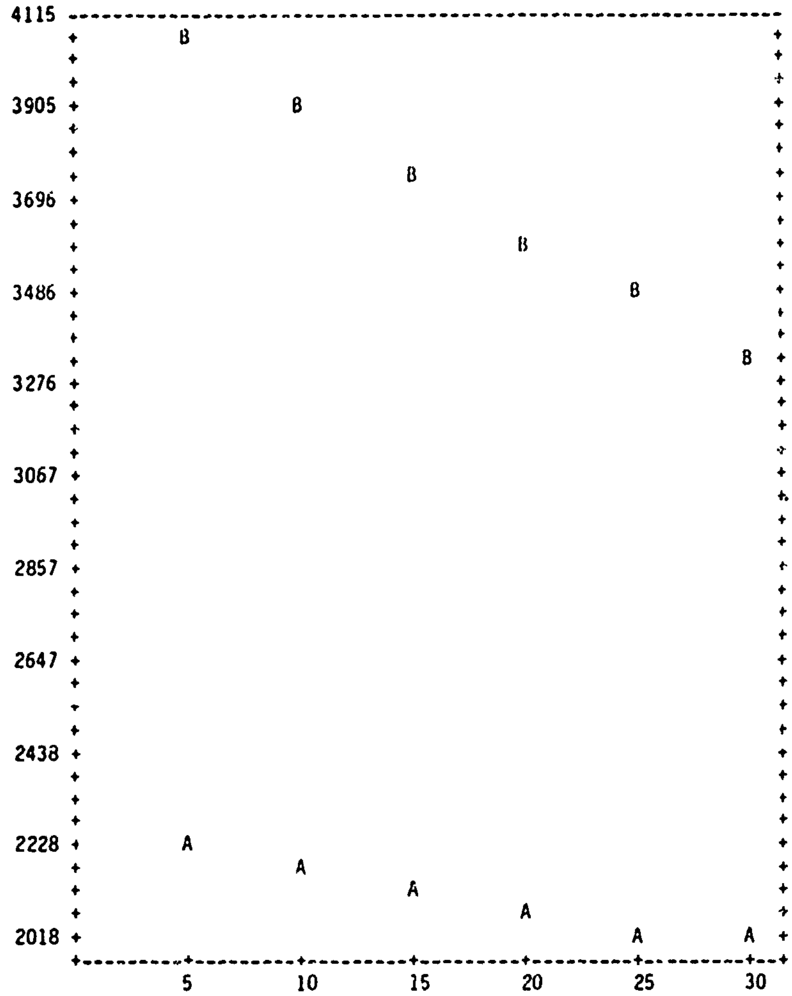
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
SURFACTANT COMPLEXING
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
SURFACTANT COMPLEXING
FOR FLOW OF 100 000 GPD.

COMPUTER OUTPUT 3.1.3.3a

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): POWDERED CARBON ADSORPTION

FOR FLOW RATE OF 100 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 10, 1981

COMPUTER OUTPUT 3.1.3.3a

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS
INDICATED OTHERWISE IN THE BODY OF TABLE. FLOW IS
100 000 GPD.

ALTERNATIVE (A)
CARBON: THERMAL REGEN (0.652 LBS TNT/LB C)

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI						
9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP						
9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN						
9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION						
9006	2	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE						
9015	2	$ 43865	$ 896	200	50000	30
CARBON COLUMN WITH THERMAL REG						
9019	1	$ 151367	$ 7227	2000	100000	30
WASTE CARBON TNK-STL OR MI						
9014	3	$ 5511	$ 0	12000	1000	30
VIRGIN CARBON STORAGE TANK						
9008	1	$ 7709	$ 0	24000	24000	30
PUMP-PRESS. BACKWASH-D.E.						
9004	1	$ 879	$ 4	1.89[a]	10000	30
CONVEYOR SCREW						
9031	1	$ 4566	$ 1000	1[b]	25[c]	30
CARBON DE-FINE TANK						
9040	1	$ 137843	$ 1000	2500	2500	30

ALTERNATIVE (B)
POWDERED CARBON ADSORPTION

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI						
9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP						
9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN						
9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION						
9006	3	$ 1047	$ 1737	2.66[d]	100000	30
SURF. STR/MIX/BODY FEED TNK						
9024	2	$ 1361	$ 0	500	0[b]	30
POWD. CARB. MIX TANK						
9036	1	$ 670	$ 1000	100	100000	30
POWD. CARB. CLARIFIER						
9037	2	$ 120975	$ 29956	5000	100000	30
THICKENER-GRAVITY						
9030	1	$ 24204	$ 3954	2000	10000	30
POLYMER ADDITION						
9033	1	$ 7515	$ 7697	500	100000	30
VACUUM FILTER POWDERED CARB.						
9034	1	$ 73622	$ 1855	1[b]	20[d]	30
CONVEYOR SCREW						
9031	2	$ 4566	$ 1000	1[b]	25[c]	30

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

```
HOLDING TANK                                             !AST-FURNACE (250 LB/DAY)
 9023  1   $ 7612  $ 0        25000   100000 30          ! 9032  1  $ 134000$ 24000   1[b]      100000  30
                                                         !
CARBON REGEN FURNACE                                     !FILTER-PRESSURE-DE
 9011  1   $ 528487$ 28449   1[b]    30[d]      30       ! 9015  2  $ 43865 $ 896     2000      50000   30
                                                         !
                                                         !PUMP-PRESS. BACKWASH-D.E.
                                                         ! 9004  1  $ 879   $ 4       1.89[a]   10000   30
                                                         !
                                                         !DRY FEEDER
                                                         ! 9044  2  $ 23489 $ 21000   100000   100000   30
                                                         !
                                                         !HOLDING TANK
                                                         ! 9023  1  $ 7612  $ 0       25000    100000   30
                                                         !

*****                       NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER                            *****
****************************************************************************************************

STUDY CONDUCTED BY GEORGE A. GARRIGAN                                            SEPTEMBER 10 1981
```

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

COMPUTER OUTPUT 3,1,3,3a
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGEN (0.652 LBS TNT/LB C))
WITH TREATMENT B (POWDERED CARBON ADSORPTION).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 974080 AND FOR ALTERNATIVE B = $ 669416;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = .68; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 100000 GALLONS: SYSTEM B = 100000 GALLONS

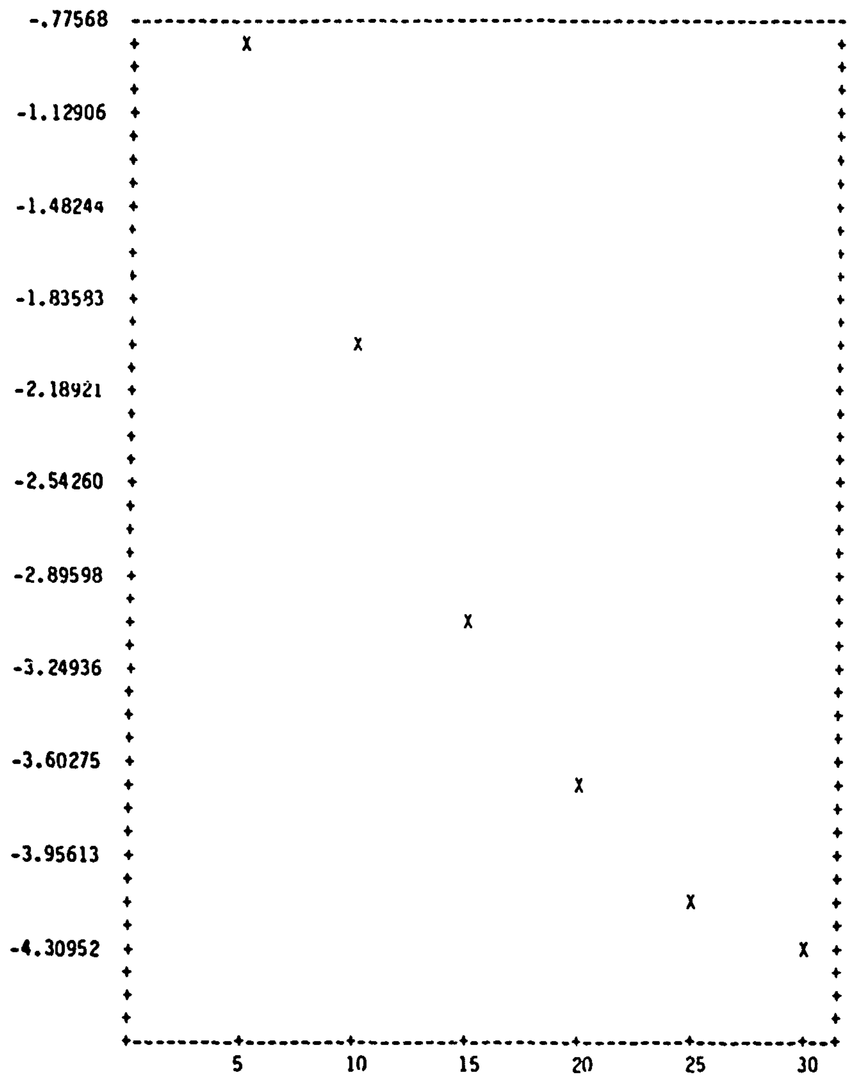
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOT. YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	235000	686000	1334000	2164000	3159000	4306000
TOT. OP. COSTS FOR ALTERN. B $	740000	2159000	4200000	6810000	9941000	13550000
CURRENT SALVAGE VALUE FOR A $	811000	649000	487000	324000	162000	0
CURRENT SALVAGE VALUE FOR B $	557000	446000	334000	223000	111000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	.28472	.11324	.04222	.01399	.00347	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	175	350	525	700	875	1050
TOT. FLOW (MGAL) FOR ALTERN B	175	350	525	700	875	1050
RSUM FOR ALTERNATIVE A	0.44713	1.05348	1.52984	1.84633	2.03995	2.15274
RSUM FOR ALTERNATIVE B	1.40700	3.31498	4.81395	5.80984	6.41913	6.77403
*THE DISCRIMINANT IS	-.7766	-2.0002	-2.9905	-3.6571	-4.0679	-4.3085
PVUC ($/MGAL PROCESSED): A $	2200	2200	2100	2100	2000	2000
PVUC ($/MGAL PROCESSED): B $	4800	4600	4500	4300	4200	4000

****

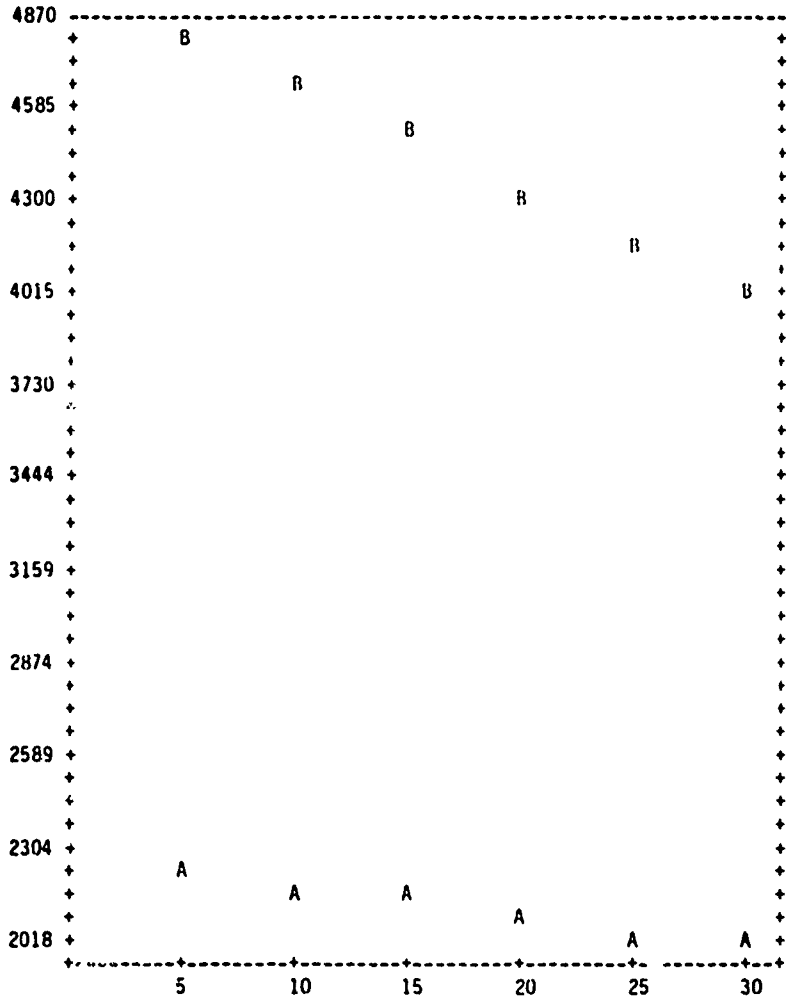
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN (0.652 LBS TNT/LB C) AND SYSTEM (B):
POWDERED CARBON ADSORPTION
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN (0.652 LBS TNT/LB C) AND SYSTEM (B):
POWDERED CARBON ADSORPTION
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

COMPUTER OUTPUT 3.1.3.4a

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGENERATION (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): ULTRAVIOLET-OZONE

FOR FLOW RATE OF 100 000 GPD

BY

VINCENT J. CICCONE

SEPTEMBER 23, 1981

COMPUTER OUTPUT 3.1.3.4a

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS INDICATED OTHERWISE IN THE BODY OF TABLE. FLOW IS 100 000 GPD.

ALTERNATIVE (A)
CARBON: THERMAL REGENERATION (0.652 LBS TNT/L

NAME OF UNIT UNDERWRITTEN BY:

NAME OF UNIT	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI	9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP	9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN	9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION	9006	2	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE	9015	2	$ 43865	$ 896	200	50000	30
CARBON COLUMN WITH THERMAL REG	9019	1	$ 151367	$ 7227	2000	100000	30
WASTE CARBON TNK-STL OR MI	9014	3	$ 5511	$ 0	12000	1000	30
VIRGIN CARBON STORAGE TANK	9008	1	$ 7709	$ 0	24000	24000	30
PUMP-PRESS. BACKWASH-D.E.	9004	1	$ 879	$ 4	1.89[a]	10000	30
CONVEYOR SCREW	9031	1	$ 4566	$ 1000	1[b]	25[c]	30
CARBON DE-FINE TANK	9040	1	$ 137843	$ 1000	2500	2500	30

ALTERNATIVE (B)
ULTRAVIOLET-OZONE

NAME OF UNIT UNDERWRITTEN BY:

NAME OF UNIT	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI	9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP	9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN	9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION	9006	2	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE	9015	2	$ 43865	$ 896	200	50000	30
OZONE PRECONTACTOR	9041	1	$ 1846	$ 0	1000	100000	30
PUMP-PRESS. EQUALIZATION	9006	1	$ 1047	$ 1737	2.66[a]	100000	30
OZONE REACTOR	9003	1	$ 326000	$ 0	10000	100000	30
UV LAMPS	9005	1	$ 1[b]	$ 208350	2304[e]	100000	30
HOLDING TANK	9023	1	$ 7612	$ 0	25000	100000	30
PUMP-PRESS. BACKWASH-D.E.	9004	1	$ 879	$ 4	1.89[a]	10000	30

--CONTINUED

NOTE: Not all values shown relate to column headings

- a = hydraulic horsepower
- b = BASIC coding
- c = length in feet
- d = square feet
- e = number of UV lamps

HOLDING TANK							
9023	1	$ 7612	$ 0	25000	100000	30	
CARBON REGEN FURNACE							
9011	1	$ 528487	$ 28449	1[b]	30[d]	30	
PUMP-PRESS. SUMP							
9007	1	$ 1786	$ 3326	7.58[a]	100000	30	
OZONE GENERATOR							
9012	1	$ 160127	$ 98784	1[b]	100000	30	
COOLER-CHILLER							
9021	1	$ 5000	$ 2000	1[b]	1[b]	30	

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

STUDY CONDUCTED BY VINCENT J CICCONE SEPTEMBER 23 1981

NOTE: Not all values shown relate to column headings,

a = hydralic horsepower
b = BASIC coding
c = length in feet
d = square feet

COMPUTER OUTPUT 3.1.3.4a
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGENERATION (0.652 LBS TNT/L)
WITH TREATMENT B (ULTRAVIOLET-OZONE).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 974080 AND FOR ALTERNATIVE B = $ 623380;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = .63; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 100000 GALLONS: SYSTEM B = 100000 GALLONS

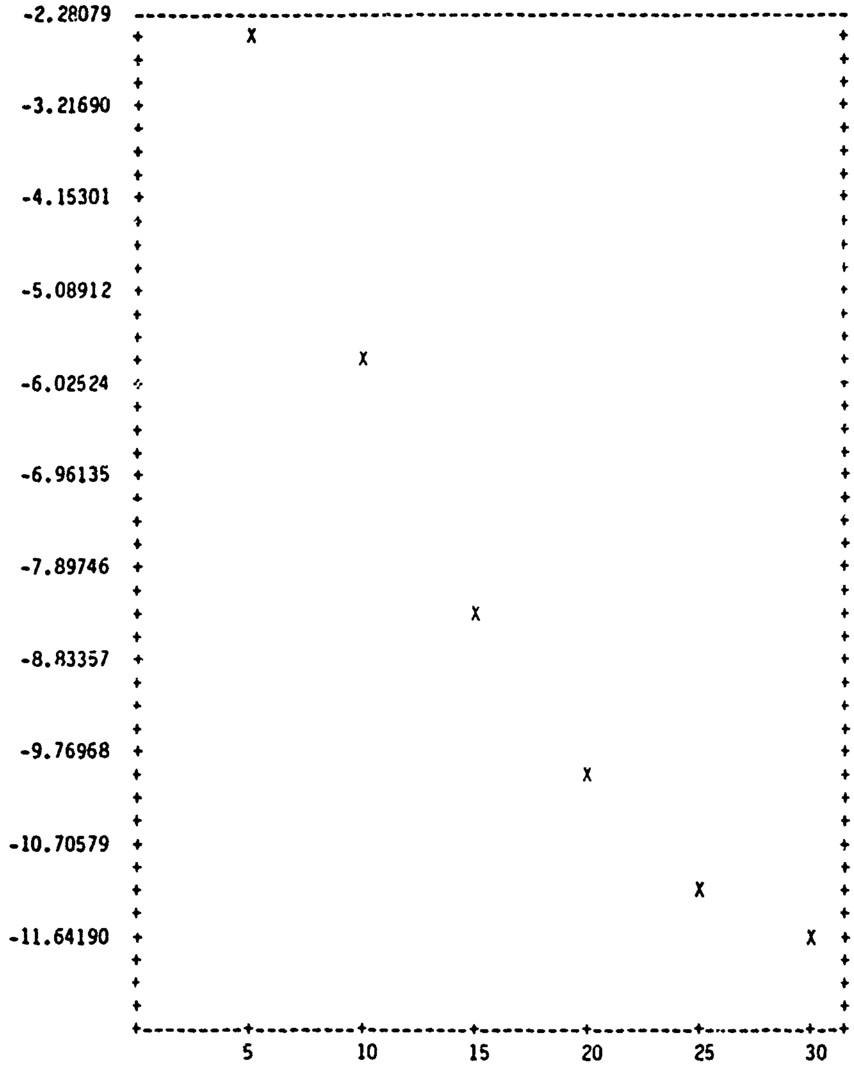
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	235000	686000	1334000	2164000	3159000	4306000
TOT. OP. COSTS FOR ALTERN. B $	1547000	4512000	8776000	14228000	20771000	28311000
CURRENT SALVAGE VALUE FOR A $	811000	649000	487000	324000	162000	0
CURRENT SALVAGE VALUE FOR B $	519000	415000	311000	207000	103000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	.26514	.10546	.03932	.01303	.00324	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	175	350	525	700	875	1050
TOT. FLOW (MGAL) FOR ALTERN B	175	350	525	700	875	1050
RSUM FOR ALTERNATIVE A	0.44713	1.05348	1.52984	1.84633	2.03995	2.15274
RSUM FOR ALTERNATIVE B	2.93979	6.92634	10.05828	12.13910	13.41214	14.15369
*THE DISCRIMINANT IS	-2.2817	-5.5721	-8.1905	-9.9400	-11.0139	-11.6409
PVUC ($/MGAL PROCESSED): A $	2200	2200	2100	2100	2000	2000
PVUC ($/MGAL PROCESSED): B $	9400	9000	8700	8300	8000	7700

****

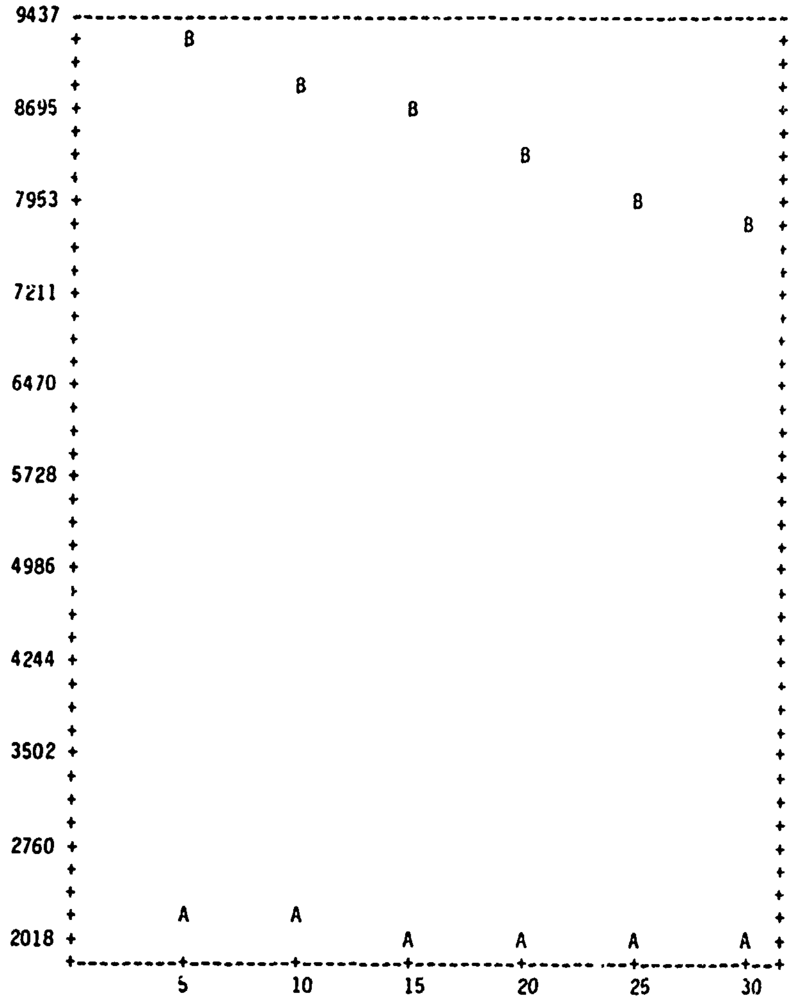
STUDY CONDUCTED BY VINCENT J CICCONE SEPTEMBER 23 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGENERATION (0.652 LBS TNT/L AND SYSTEM (B):
ULTRAVIOLET-OZONE
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY VINCENT J CICCONE SEPTEMBER 23 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGENERATION (0.652 LBS TNT/L AND SYSTEM (B):
ULTRAVIOLET-OZONE
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY VINCENT J CICCONE SEPTEMBER 23 1981

COMPUTER OUTPUT 3.1.3.5a

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)(6)

WITH SYSTEM (B): LIQUID-LIQUID EXTRACTION

FOR FLOW RATE OF 100 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 10, 1981

COMPUTER OUTPUT 3.1.3.5a

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS
INDICATED OTHERWISE IN THE BODY OF TABLE. FLOW IS
100 000 GPD.

ALTERNATIVE (A)
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI						
9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP						
9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN						
9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION						
9006	2	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE						
9015	2	$ 43865	$ 896	200	50000	30
CARBON COLUMN WITH THERMAL REG						
9019	1	$ 151367	$ 7227	2000	100000	30
WASTE CARBON TNK-STL OR MI						
9014	3	$ 5511	$ 0	12000	1000	30
VIRGIN CARBON STORAGE TANK						
9008	1	$ 7709	$ 0	24000	24000	30
PUMP-PRESS. BACKWASH-D.E.						
9004	1	$ 879	$ 4	1.89[a]	10000	30
CONVEYOR SCREW						
9031	1	$ 4566	$ 1000	1[b]	25[c]	30
CARBON DE-FINE TANK						
9040	1	$ 137843	$ 1000	2500	2500	30

ALTERNATIVE (B)
LIQUID-LIQUID EXTRACTION

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI						
9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP						
9007	2	$ 1786	$ 3326	7.58[a]	100000	30
EQUALIZATION/SEDIMENTATION TAN						
9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION						
9006	3	$ 1047	$ 1737	2.66[a]	100000	30
FILTER-PRESSURE-DE						
9015	2	$ 43865	$ 896	200	50000	30
SOLVENT EXTRACTION						
9045	2	$ 1062127	$ 775931	6000	0[b]	30
SUMP-STL OR MI						
9028	1	$ 6900	$ 0	20000	100000	30
FRACTIONAL DISTILLATION						
9046	1	$ 482170	$ 92395	1.29[f]	1000000	30
SURF. STR/MIX/BODY FEED TNK						
9024	1	$ 1361	$ 0	500	0[b]	30
CHEMICAL FEEDER						
9025	1	$ 3000	$ 1000	1[b]	1[b]	30
HOLDING TANK						
9023	1	$ 7612	$ 0	25000	100000	30

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
f = ten thousand pounds per day

HOLDING TANK							
	9023	1	$ 7612	$ 0	25000	100000	30
CARBON REGEN FURNACE							
	9011	1	$ 528487	$ 28449	1[b]	30[d]	30
PUMP-PRESS. BACKWASH-D.E.							
	9004	1	$ 879	$ 4	1.89[a]	10000	30
SURF. STR/MIX/BODY FEED TNK							
	9024	1	$ 1361	$ 0	500	0[b]	30
CHEMICAL FEEDER							
	9025	1	$ 3000	$ 1000	1[b]	1[b]	30

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

STUDY CONDUCTED BY GEORGE A. GARRIGAN — SEPTEMBER 10 1981

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

COMPUTER OUTPUT 3.1.3.5a
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGEN. (0.052 LBS TNT/LB C))
WITH TREATMENT B (LIQUID-LIQUID EXTRACTION).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 974080 AND FOR ALTERNATIVE B = $ 2750668;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 2.82; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 100000 GALLONS: SYSTEM B = 100000 GALLONS

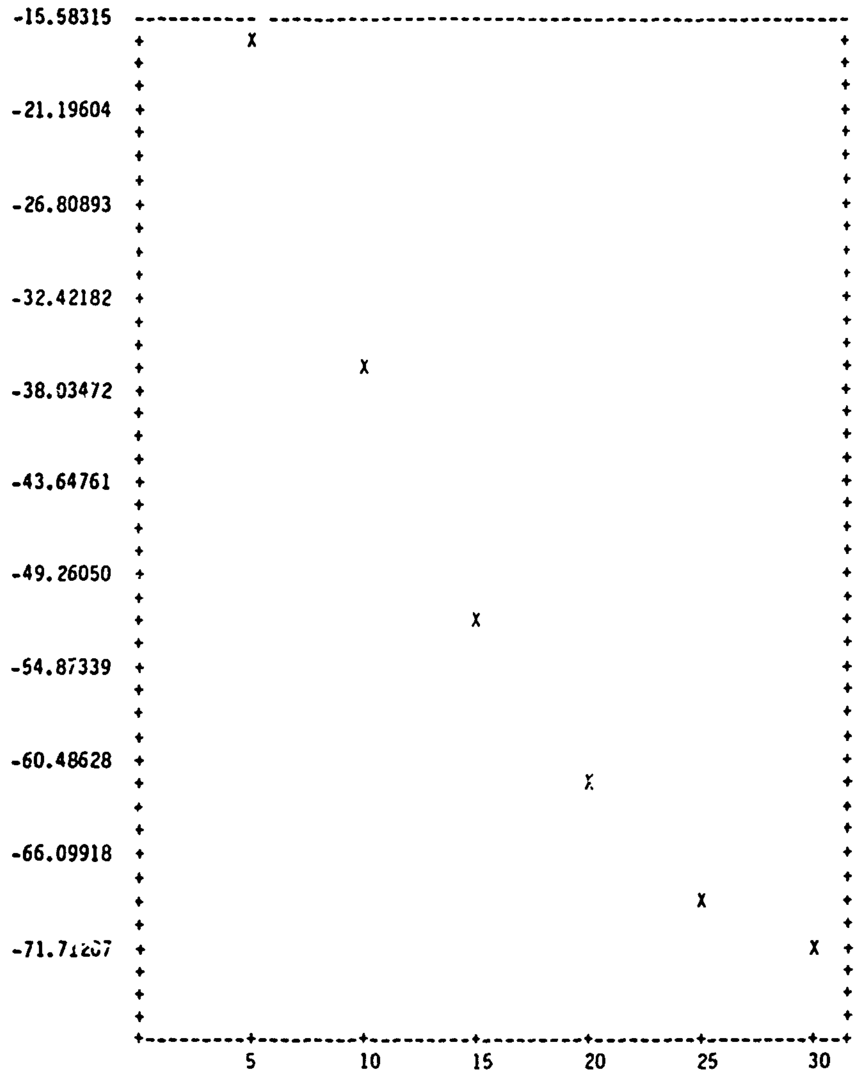
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	235000	686000	1334000	2164000	3159000	4306000
TOT. OP. COSTS FOR ALTERN. B $	7876000	22967000	44668000	72423000	105723000	144103000
CURRENT SALVAGE VALUE FOR A $	811000	649000	487000	324000	162000	0
CURRENT SALVAGE VALUE FOR B $	2292000	1833000	1375000	916000	458000	-1000
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	1.16996	.46534	.17351	.05751	.01429	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	175	350	525	700	875	1050
TOT. FLOW (MGAL) FOR ALTERN B	175	350	525	700	875	1050
RSUM FOR ALTERNATIVE A	0.44713	1.05348	1.52984	1.84633	2.03995	2.15274
RSUM FOR ALTERNATIVE B	14.96308	35.25396	51.19501	61.78607	68.26564	72.03998
*THE DISCRIMINANT IS	-15.5841	-35.7237	-51.3769	-61.7264	-68.0403	-71.7110
PVUC ($/MGAL PROCESSED): A $	2200	2200	2100	2100	2000	2000
PVUC ($/MGAL PROCESSED): B $	47600	45700	43900	42200	40600	39100

****

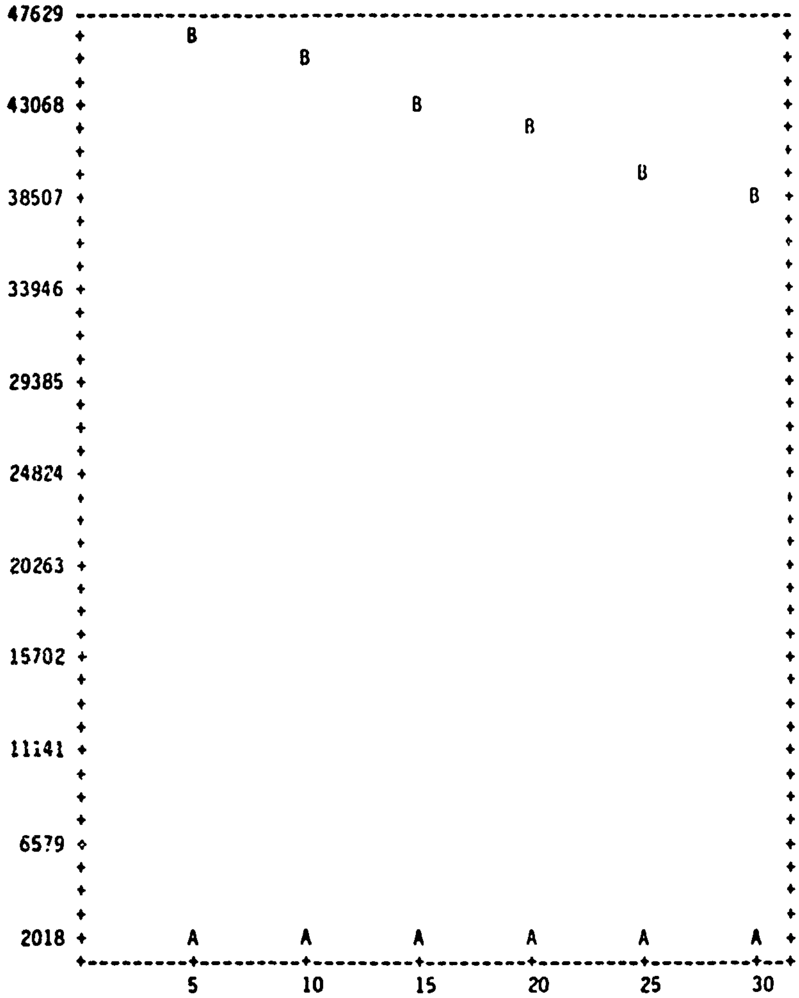
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
LIQUID-LIQUID EXTRACTION
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
LIQUID-LIQUID EXTRACTION
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

COMPUTER OUTPUT 3.1.3.6a

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): ULTRAFILTRATION

FOR FLOW RATE OF 100 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 10, 1981

COMPUTER OUTPUT 3.1.3.6a

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS
INDICATED OTHERWISE IN THE BODY OF TABLE. FLOW IS
100 000 GPD.

ALTERNATIVE (A) CARBON: THERMAL REGEN. (0.652 LBSTNT/LB C)								ALTERNATIVE (B) ULTRAFILTRATION							
NAME OF UNIT UNDERWRITTEN BY:	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS	NAME OF UNIT UNDERWRITTEN BY:	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	LIF YRS
SUMP-STL OR MI	9028	1	$ 6900	$ 0	20000	100000	30	SUMP-STL OR MI	9028	1	$ 6900	$ 0	20000	100000	30
PUMP-PRESS. SUMP	9007	2	$ 1786	$ 3326	7.58^{a}	100000	30	PUMP-PRESS. SUMP	9007	2	$ 1786	$ 3326	7.58^{a}	100000	30
EQUALIZATION/SEDIMENTATION TAN	9018	1	$ 18777	$ 0	100000	25000	30	EQUALIZATION/SEDIMENTATION TAN	9018	1	$ 18777	$ 0	100000	25000	30
PUMP-PRESS. EQUALIZATION	9006	2	$ 1047	$ 1737	2.66^{a}	100000	30	PUMP-PRESS. EQUALIZATION	9006	2	$ 1047	$ 1737	2.66^{a}	100000	30
FILTER-PRESSURE-DE	9015	2	$ 43865	$ 896	200	50000	30	FILTER-PRESSURE-DE	9015	2	$ 43865	$ 896	200	50000	30
CARBON COLUMN WITH THERMAL REG	9019	1	$ 151367	$ 7227	2000	100000	30	UF MEMBRANE MODULE	9027	10	$ 1513889	$ 219239	$.1^{g}$	0^{b}	30
WASTE CARBON TNK-STL OR MI	9014	3	$ 5511	$ 0	12000	1000	30	UF-RECIRC. PUMP	9026	10	$ 5774	$ 13844	75.6^{a}	4320000	30
VIRGIN CARBON STORAGE TANK	9008	1	$ 7709	$ 0	24000	24000	30	PUMP-PRESS. BACKWASH-D.E.	9004	1	$ 879	$ 4	1.89^{a}	10000	30
PUMP-PRESS. BACKWASH-D.E.	9004	1	$ 879	$ 4	1.89^{a}	10000	30	HOLDING TANK	9023	2	$ 7612	$ 0	25000	100000	30
CONVEYOR SCREW	9031	1	$ 4566	$ 1000	1^{b}	25^{c}	30								
CARBON DE-FINE TANK	9040	1	$ 137843	$ 1000	2500	2500	30								

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet
g = million gallons per day

HOLDING TANK							
9023	1	$ 7612	$ 0	25000	100000	30	!
CARBON REGEN FURNACE							
9011	1	$ 528487	$ 28449	1[b]	30[d]	30	!

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****
****

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

NOTE: Not all values shown relate to column headings,

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

COMPUTER OUTPUT 3.1.3.6a
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGEN. (0.652 LBSTNT/LB C))
WITH TREATMENT B (ULTRAFILTRATION).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 974080 AND FOR ALTERNATIVE B = $15331815;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 15.73; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 100000 GALLONS SYSTEM B = 100000 GALLONS

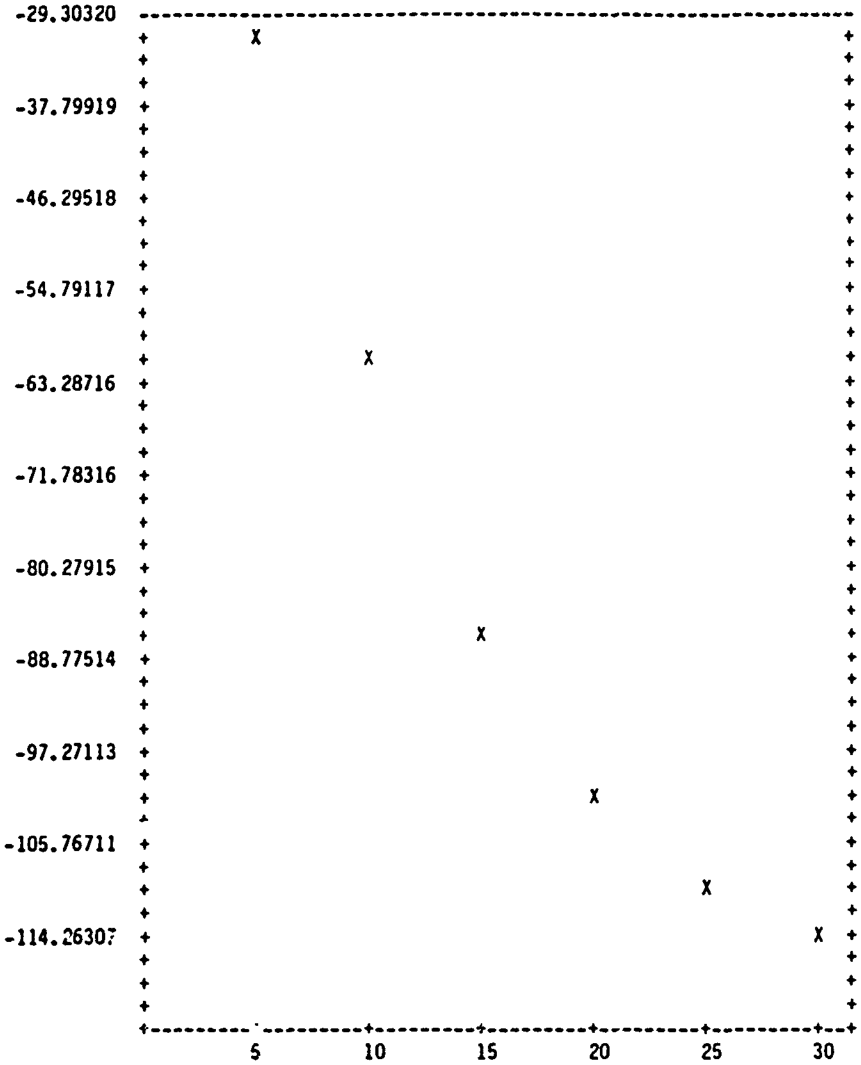
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	235000	686000	1334000	2164000	3159000	4306000
TOT. OP. COSTS FOR ALTERN. B $	11116000	32416000	63043000	102215000	149214000	203382000
CURRENT SALVAGE VALUE FOR A $	811000	649000	487000	324000	162000	0
CURRENT SALVAGE VALUE FOR B $	12776000	10221000	7665000	5110000	2555000	-1000
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	6.52120	2.59375	.96716	.32056	.07968	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	175	350	525	700	875	1050
TOT. FLOW (MGAL) FOR ALTERN B	175	350	525	700	875	1050
RSUM FOR ALTERNATIVE A	0.44713	1.05348	1.52984	1.84633	2.03995	2.15274
RSUM FOR ALTERNATIVE B	21.11845	49.75642	72.25516	87.20307	96.34814	????????
*THE DISCRIMINANT IS	-29.3042	-61.0137	-84.5593	-99.7963	????????	????????
PVUC ($/MGAL PPOCESSED): A $	2200	2200	2100	2100	2000	2000
PVUC ($/MGAL PROCESSED): B $	78100	75400	72900	70500	68300	66100

****

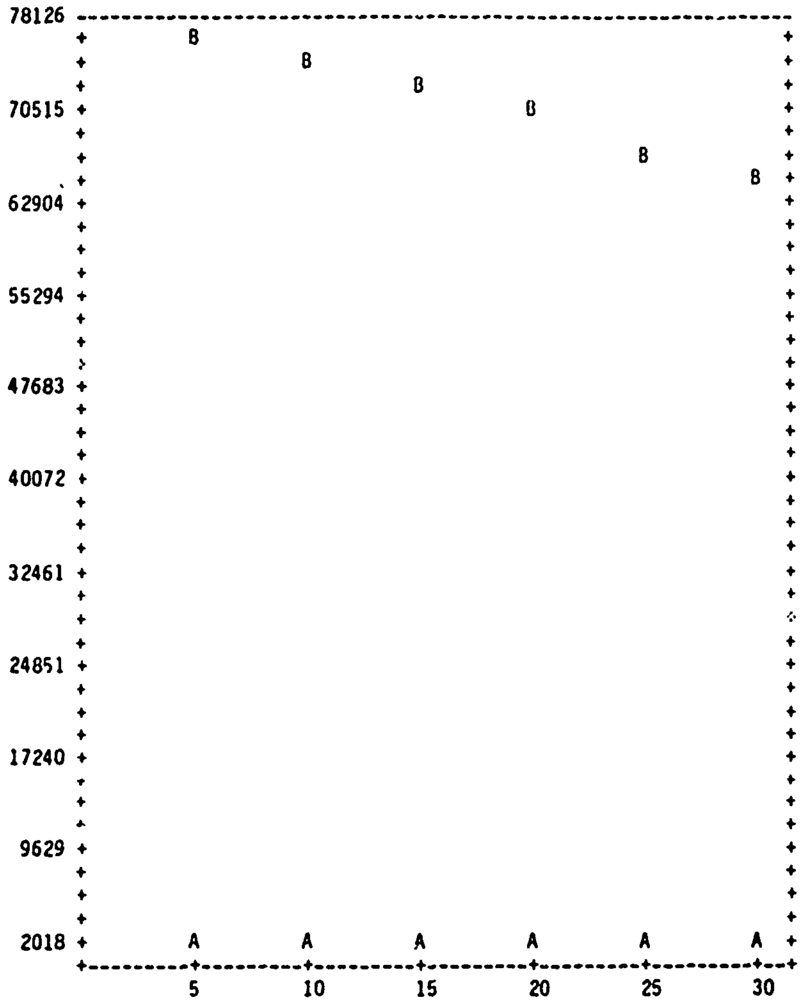
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBSTNT/LB C) AND SYSTEM (B):
ULTRAFILTRATION
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBSTNT/LB C) AND SYSTEM (B):
ULTRAFILTRATION
FOR FLOW OF 100 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

COMPUTER OUTPUT 3.1.3.1b

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: NO REGENERATION (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)[6]

FOR FLOW RATE OF 1 000 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 9, 1981

COMPUTER OUTPUT 3.1.3.1b
LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS INDICATED OTHERWISE IN THE BODY OF THE TABLE. THE LIFE SPAN FOR ALL UNITS IS SET AT 30 YEARS AND THE FLOW IS 1 000 000 GPD.

ALTERNATIVE (A) CARBON: NO REGENERATION (0.652 LBS TNT/LB C)						ALTERNATIVE (B) CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)					
NAME OF UNIT UNDERWRITTEN BY:						NAME OF UNIT UNDERWRITTEN BY:					
CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI						SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000	9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP						PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58[a]	1000000	9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN						EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	1000000	9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION						PUMP-PRESS. EQUALIZATION					
9206	2	$ 1047	$ 1737	2.66[a]	1000000	9206	2	$ 1047	$ 1737	2.66[a]	1000000
MIXED MEDIA PRESS. FILT.						MIXED MEDIA PRESS. FILT.					
9239	4	$ 113523	$ 460	5000	340000	9239	4	$ 113523	$ 460	5000	340000
CARBON COLUMN-GRANULAR						CARBON COLUMN WITH THERMAL REG					
9213	1	$ 359106	$ 748216	21000	1000000	9219	1	$ 359106	$ 47821	21000	1000000
CONVEYOR SCREW						CONVEYOR SCREW					
9231	3	$ 4566	$ 2000	1[b]	25[c]	9231	3	$ 4566	$ 2000	1[b]	25[c]
WASTE CARBON TNK-STL OR MI						WASTE CARBON TNK-STL OR MI					
9214	3	$ 7612	$ 0	25000	10000	9214	3	$ 7612	$ 0	25000	10000
HOLDING TANK						CARBON REGEN FURNACE					
9223	1	$ 7612	$ 0	25000	1000000	9211	1	$ 1339783	$ 147598	1[b]	300[d]
PUMP-PRESS. BACKWASH						CARBON DE-FINE TANK					
9204	1	$ 3700	$ 83	31.6[a]	100000	9240	1	$ 140852	$ 2000	25000	25000
VIRGIN CARBON STORAGE TANK						HOLDING TANK					
9208	1	$ 7709	$ 0	24000	24000	9223	1	$ 7612	$ 0	25000	1000000

--CONTINUED

NOTE: Not all values shown relate to colum headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

```
!PUMP-PRESS. BACKWASH
! 9204  1  $ 3700  $ 83       31.6a   100000
!
!VIRGIN CARBON STORAGE TANK
! 9208  1  $ 7709  $ 0        24000   24000
!
```

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

****

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 9 1981

NOTE: Not all values shown relate to column headings.
a = hydraulic horsepower

COMPUTER OUTPUT 3.1.3.1b
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: NO REGENERATION (0.652 LBS TNT/LB C))
WITH TREATMENT B (CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 1029786 AND FOR ALTERNATIVE B = $ 2510422;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 2.43; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA', = 1.0000
DAILY FLOW IN SYSTEM A = 1000000 GALLONS: SYSTEM B = 1000000 GALLONS

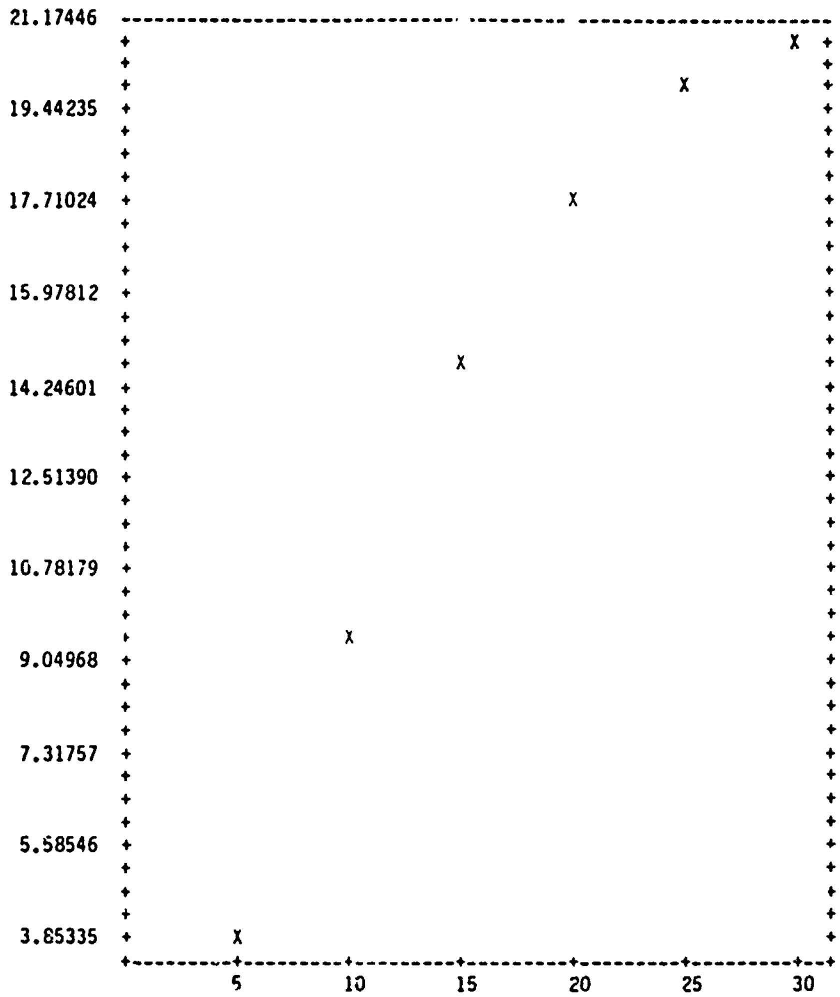
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	3636000	10602000	20620000	33432000	48805000	66522000
TOT. OP. COSTS FOR ALTERN. B $	1022000	2981000	5798000	9401000	13723000	18705000
CURRENT SALVAGE VALUE FOR A $	858000	686000	514000	343000	171000	-1000
CURRENT SALVAGE VALUE FOR B $	2092000	1673000	1255000	836000	418000	-1000
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	1.01001	.40172	.14979	.04965	.01234	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	1750	3500	5250	7000	8750	10500
TOT. FLOW (MGAL) FOR ALTERN B	1750	3500	5250	7000	8750	10500
RSUM FOR ALTERNATIVE A	6.53375	15.39395	22.35475	26.97942	29.80878	31.45688
RSUM FOR ALTERNATIVE B	1.83728	4.32874	6.28611	7.58656	8.38217	8.84561
*THE DISCRIMINANT IS	3.8543	9.0643	14.7191	17.9843	19.9960	21.1734
PVUC ($/MGAL PROCESSED): A $	2100	2000	2000	1900	1800	1700
PVUC ($/MGAL PROCESSED): B $	820	790	770	750	730	710

****

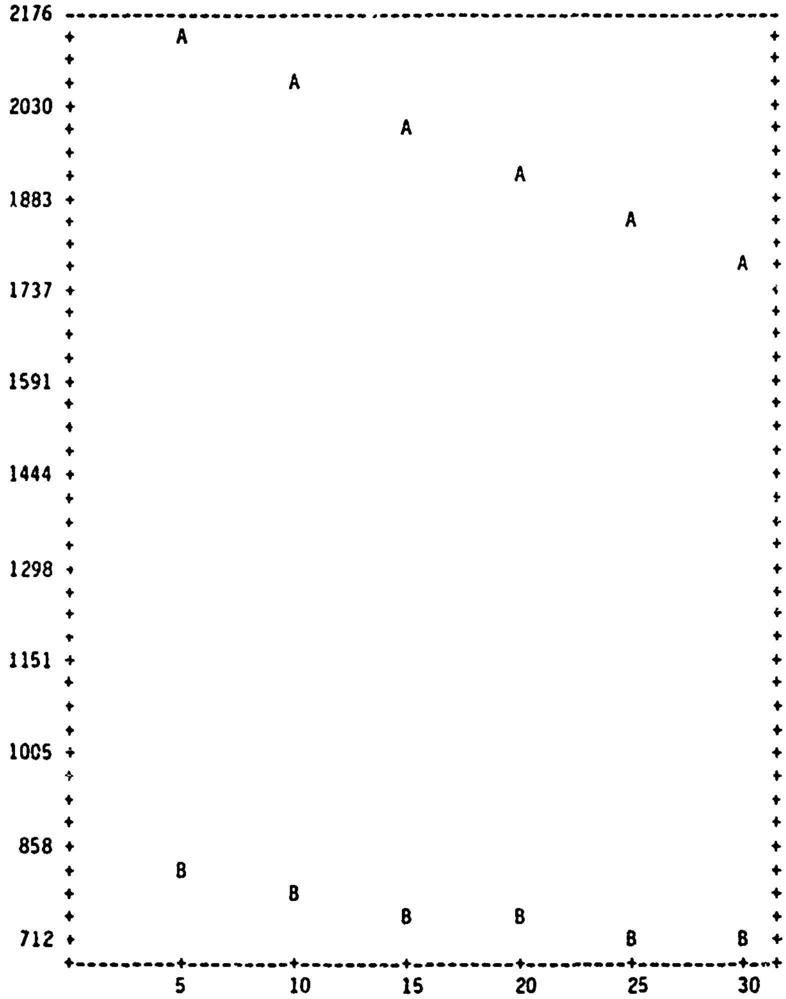
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 9 1981.

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: NO REGENERATION (0.652 LBS TNT/LB C) AND SYSTEM (B):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 9 1981



PVUC \$/KGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: NO REGENERATION (0.652 LBS TNT/LB C) AND SYSTEM (B):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 9 1981

COMPUTER OUTPUT 3.1.3.2b

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): SURFACTANT COMPLEXING

FOR FLOW RATE OF 1 000 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 10, 1981

COMPUTER OUTPUT 3.1.3.2b

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS INDICATED OTHERWISE IN THE BODY OF THE TABLE. THE LIFE SPAN FOR ALL UNITS IS SET AT 30 YEARS AND THE FLOW IS 1 000 000 GPD.

ALTERNATIVE (A) — CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)

NAME OF UNIT UNDERWRITTEN BY:	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI	9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP	9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN	9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION	9206	2	$ 1047	$ 1737	2.66[a]	1000000
MIXED MEDIA PRESS. FILT.	9239	4	$ 113523	$ 460	5000	340000
CARBON COLUMN WITH HERMAL REG	9219	1	$ 359106	$ 47821	21000	1000000
CONVEYOR SCREW	9231	3	$ 4566	$ 2000	1[b]	25[c]
WASTE CARBON TNK-STL OR MI	921[illegible]	3	$ 7612	$ 0	25000	10000
CARBON REGEN FURNACE	92[illegible]	1	$ 1339783	$ 147598	1[b]	300[d]
CARBON DE-FINE TANK	9240	1	$ 140852	$ 2000	25000	25000
HOLDING TANK	9223	1	$ 7612	$ 0	25000	1000000

ALTERNATIVE (B) — SURFACTANT COMPLEXING

NAME OF UNIT UNDERWRITTEN BY:	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI	9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP	9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN	9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION	9206	5	$ 1047	$ 1737	2.66[a]	1000000
SURF. STR/MIX/BODY FEED TNK	9224	3	$ 1361	$ 0	500	0[b]
CHEMICAL FEEDER	9225	3	$ 3000	$ 1000	1[b]	1[b]
SURFACT REACT TANK	9235	2	$ 9612	$ 264500	25000	1000000
VACUUM FILTER POWDERED CARB.	9234	1	$ 282495	$ 11829	1[b]	200[d]
NEUTRALIZATION TANK	9222	1	$ 9612	$ 789500	25000	1000000

--CONTINUED

NOTE: Not all values shown relate to column headings,

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

PUMP-PRESS. BACKWASH						
9204	1	$ 3700	$ 83	31.6[a]	100000	
VIRGIN CARBON STORAGE TANK						
9208	1	$ 7709	$ 0	24000	24000	

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

NOTE: Not all values shown relate to column headings.
a = hydraulic horsepower

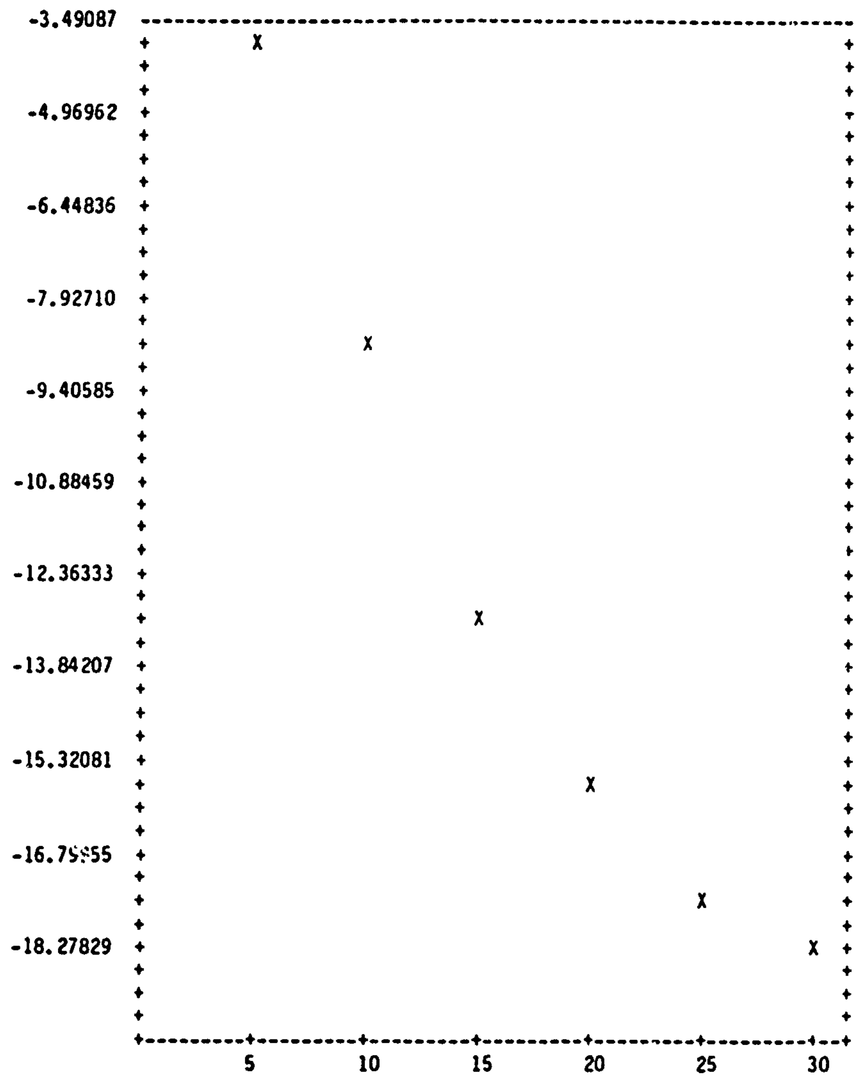
COMPUTER OUTPUT 3.1.3.2b
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C))
WITH TREATMENT B (SURFACTANT COMPLEXING).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 2510422 AND FOR ALTERNATIVE B = $ 489588;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = .19; INTEREST RATE = .15;
INFLATION RATE = .13; OW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 1000000 GALLONS: SYSTEM B - 1000000 GALLONS

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	1022000	2981000	5798000	9401000	13723000	18706000
TOT. OP. COSTS FOR ALTERN. B $	6399000	18661000	36292000	58843000	85899000	117082000
CURRENT SALVAGE VALUE FOR A $	2092000	1673000	1255000	836000	418000	-1000
CURRENT SALVAGE VALUE FOR B $	407000	325000	244000	162000	81000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	.08063	.03207	.01195	.00396	.00098	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	1750	3500	5250	7000	8750	10500
TOT. FLOW (MGAL) FOR ALTERN B	1750	3500	5250	7000	8750	10500
RSUM FOR ALTERNATIVE A	0.75366	1.77567	2.57859	3.11204	3.43841	3.62852
RSUM FOR ALTERNATIVE B	4.71723	11.11411	16.13966	19.47858	21.52131	22.71121
*THE DISCRIMINANT IS	-3.4918	-8.6657	-12.8051	-15.5775	-17.2816	-18.2773
PVUC ($/MGAL PROCESSED): A $	820	790	770	750	730	710
PVUC ($/MGAL PROCESSED): B $	3700	3500	3400	3200	3100	3000

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

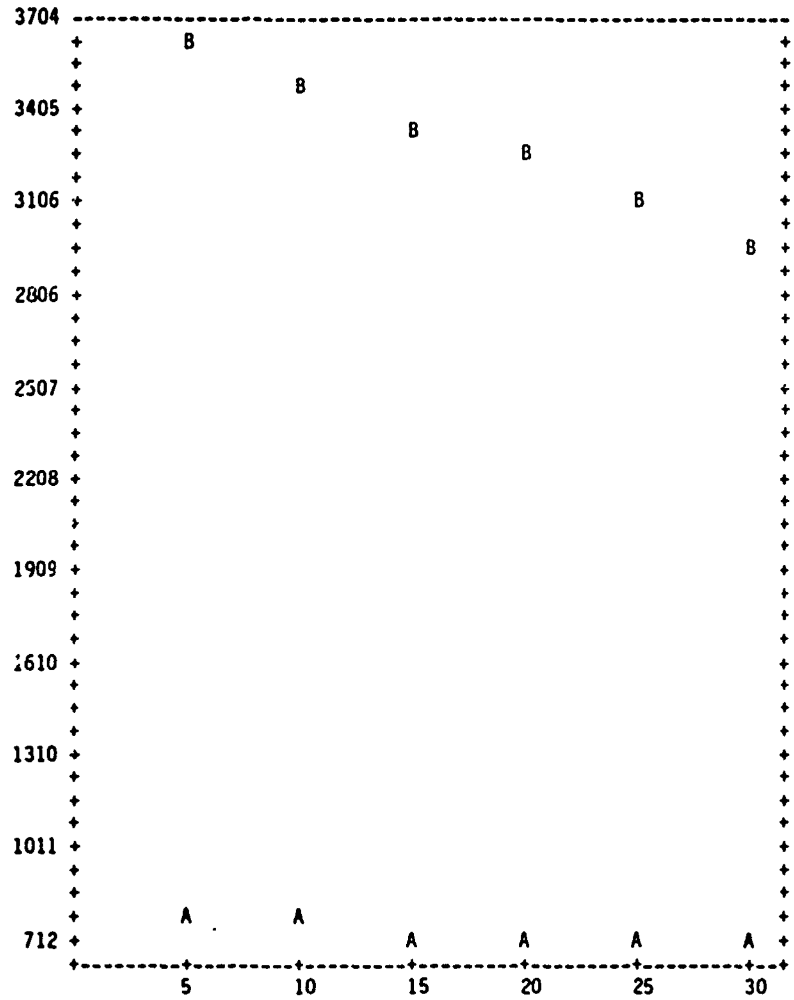
* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
SURFACTANT COMPLEXING
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN

SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
SURFACTANT COMPLEXING
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

COMPUTER OUTPUT 3.1.3.3b

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): POWDERED CARBON ADSORPTION

FOR FLOW RATE OF 1 000 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 10, 1981

COMPUTER OUTPUT 3.1.3.3b

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS INDICATED OTHERWISE IN THE BODY OF THE TABLE. THE LIFE SPAN FOR ALL UNITS IS SET AT 30 YEARS AND THE FLOW IS 1 000 000 GPD.-

ALTERNATIVE (A)
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION					
9206	2	$ 1047	$ 1737	2.66[a]	1000000
MIXED MEDIA PRESS. FILT.					
9239	4	$ 113523	$ 460	5000	340000
CARBON COLUMN WITH THERMAL REG					
9219	1	$ 359106	$ 47821	21000	1000000
CONVEYOR SCREW					
9231	3	$ 4566	$ 2000	1[b]	25[c]
WASTE CARBON TNK-STL OR MI					
9214	3	$ 7612	$ 0	25000	10000
CARBON REGEN FURNACE					
9211	1	$ 1339783	$ 147598	1[b]	300[d]
CARBON DE-FINE TANK					
9240	1	$ 140852	$ 2000	25000	25000
HOLDING TANK					
9223	1	$ 7612	$ 0	25000	1000000

ALTERNATIVE (B)
POWDERED CARBON ADSORPTION

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION					
9206	3	$ 1047	$ 1737	2.66[a]	1000000
SURF. STR/MIX/BODY FEED TNK					
9224	2	$ 1361	$ 0	500	0[b]
POWD. CARB. MIX TANK					
9236	1	$ 1846	$ 3000	1000	1000000
POWD. CARB. CLARIFIER					
9237	2	$ 247000	$ 221570	36000	1000000
THICKNER-GRAVITY					
9230	1	$ 24204	$ 3954	2000	10000
POLYMER ADDITION					
9233	1	$ 18482	$ 18098	500	1000000
VACUUM FILTER POWDERED CARB.					
9234	1	$ 282495	$ 11829	1[b]	200[d]
CONVEYOR SCREW					
9231	2	$ 4566	$ 2000	1[b]	25[c]

--CONTINUED

NOTE: Not all values shown relate to column headings,

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet

PUMP-PRESS. BACKWASH
9204 1 $ 3700 $ 83 31.6[a] 100000

VIRGIN CARBON STORAGE TANK
9208 1 $ 7709 $ 0 24000 24000

!AST-FURNACE (250 LB/DAY)
! 9232 1 $ 1500000 $ 238000 1[b] 1000000
!
!MIXED MEDIA PRESS. FILT.
! 9239 4 $ 113523$ 460 5000 340000
!
!PUMP-PRESS. BACKWASH
! 9204 1 $ 3700 $ 83 31.6[a] 100000
!
!DRY FEEDER
! 9244 2 $ 36412 $ 123000 1000000 1000000
!
!HOLDING TANK
! 9223 1 $ 7612 $ 0 25000 1000000
!

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****
****

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding

COMPUTER OUTPUT 3.1.3.3b
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C))
WITH TREATMENT B (POWDERED CARBON ADSORPTION).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 2510422 AND FOR ALTERNATIVE B = $ 3033189;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 1.20; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 1000000 GALLONS: SYSTEM B = 1000000 GALLONS

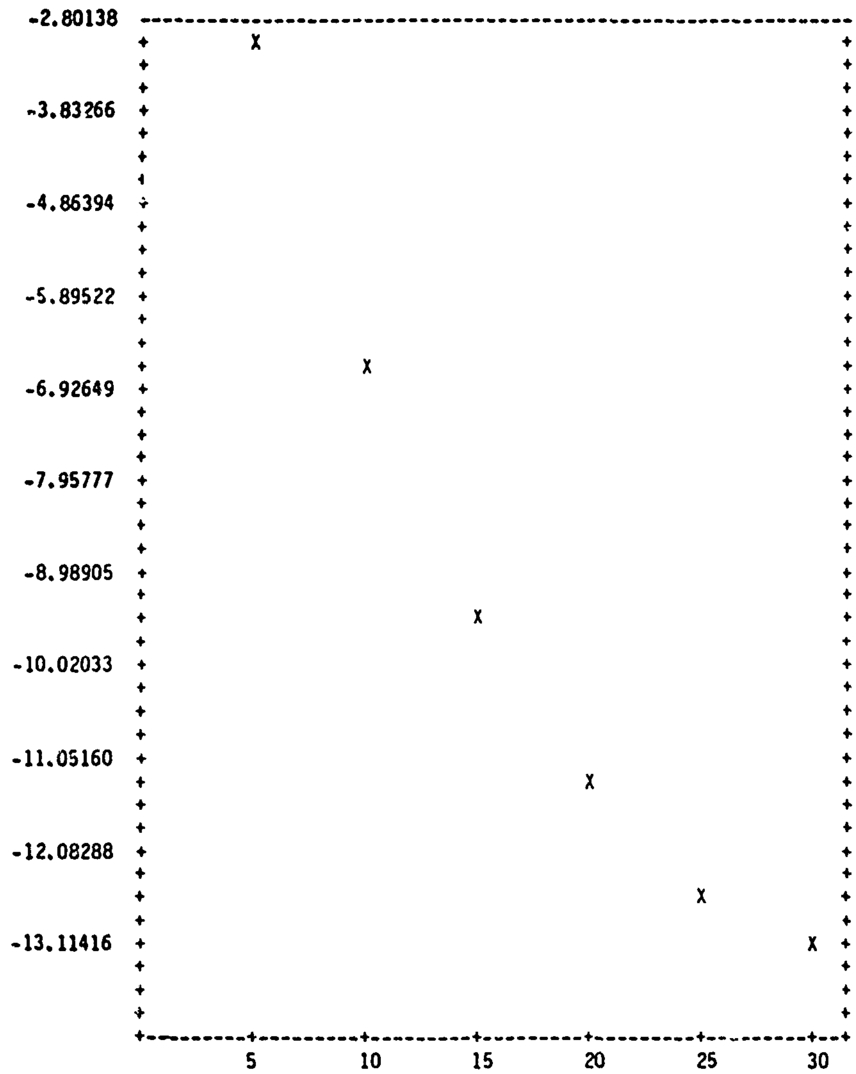
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	1022000	2981000	5798000	9401000	13723000	18706000
TOT. OP. COSTS FOR ALTERN. B $	4658000	13585000	26420000	42836000	62533000	85234000
CURRENT SALVAGE VALUE FOR A $	2092000	1673000	1255000	836000	418000	-1000
CURRENT SALVAGE VALUE FOR B $	2527000	2022000	1516000	1011000	505000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	.50059	.19910	.07424	.02460	.00611	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	1750	3500	5250	7000	8750	10500
TOT. FLOW (MGAL) FOR ALTERN B	1750	3500	5250	7000	8750	10500
RSUM FOR ALTERNATIVE A	0.75366	1.77567	2.57859	3.11204	3.43841	3.62852
RSUM FOR ALTERNATIVE B	3.43408	8.09092	11.74945	14.18014	15.66722	16.53345
*THE DISCRIMINANT IS	-2.8023	-6.4891	-9.3663	-11.2720	-12.4359	-13.1131
PVUC ($/MGAL PROCESSED): A $	820	790	770	750	730	710
PVUC ($/MGAL PROCESSED): B $	2900	2800	2700	2600	2500	2400

****

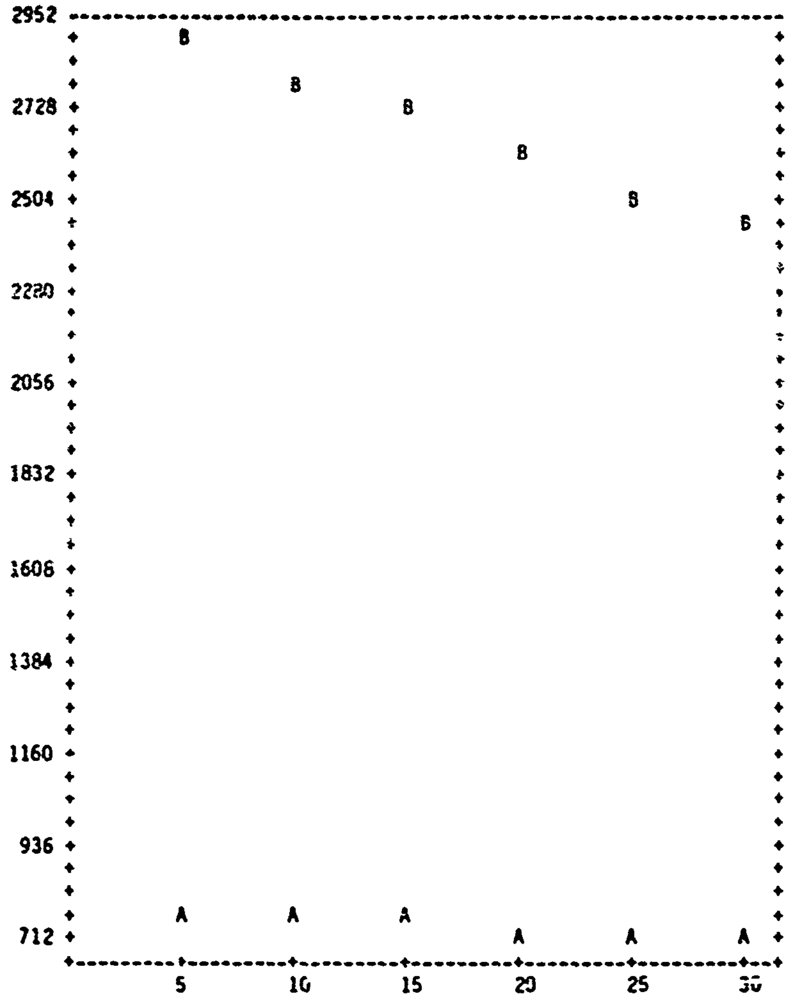
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
POWDERED CARBON ADSORPTION
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
POWDERED CARBON ADSORPTION
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

COMPUTER OUTPUT 3.1.3.4b

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGENERATION (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): ULTRAVIOLET-OZONE (8 LAMPS/SQ.FT.)

FOR FLOW RATE OF 1 000 000 GPD

BY

VINCENT J. CICCONE

SEPTEMBER 23, 1981

COMPUTER OUTPUT 3.1.3.4b
LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS
INDICATED OTHERWISE IN THE BODY OF THE TABLE. THE
LIFE SPAN FOR ALL UNITS IS SET AT 30 YEARS AND THE
FLOW IS 1 000 000 GPD.

ALTERNATIVE (A) CARBON:THERMAL REGENERATION (0.652 LBS TNT/LB						ALTERNATIVE (C) ULTRAVIOLET-OZONE (8 LAMPS/SQ.FT)					
NAME OF UNIT UNDERWRITTEN BY:						NAME OF UNIT UNDERWRITTEN BY:					
CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD	CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI						SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000	9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP						PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58[a]	1000000	9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN						EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	1000000	9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION						PUMP-PRESS. EQUALIZATION					
9206	2	$ 1047	$ 1737	2.66[a]	1000000	9206	2	$ 1047	$ 1737	2.66[a]	1000000
MIXED MEDIA PRESS. FILT.						MIXED MEDIA PRESS. FILT.					
9239	4	$ 113523	$ 460	5000	340000	9239	4	$ 113523	$ 460	5000	340000
CARBON COLUMN WITH THERMAL REG						OZONE PRECONTACTOR					
9219	1	$ 359106	$ 47821	21000	1000000	9241	1	$ 5086	$ 0	10000	1000000
CONVEYOR SCREW						PUMP-PRESS. EQUALIZATION					
9231	3	$ 4566	$ 2000	1[b]	25[c]	9206	1	$ 1047	$ 1737	2.66[a]	1000000
WASTE CARBON TNK-STL OR MI						OZONE REACTOR					
9214	3	$ 7612	$ 0	25000	10000	9203	4	$ 652000	$ 0	30000	1000000
CARBON REGEN FURNACE						UV LAMPS/REACTOR TANK					
9211	1	$ 1339783	$ 147598	1[b]	300[d]	9205	4	$ 1[b]	$ 520875	5760[e]	1000000
CARBON DE-FINE TANK						HOLDING TANK					
9240	1	$ 140852	$ 2000	25000	25000	9223	1	$ 7612	$ 0	25000	1000000
HOLDING TANK						PUMP-PRESS. BACKWASH					
9223	1	$ 7612	$ 0	25000	1000000	9204	1	$ 3700	$ 83	31.6[a]	100000

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet
e = number of UV lamps

PUMP-PRESS. BACKWASH						
9204	1	$ 3700	$ 83	31.6[a]	100000	
VIRGIN CARBON STORAGE TANK						
9208	1	$ 7709	$ 0	24000	24000	

PUMP-PRESS. SUMP					
9207	1	$ 1786	$ 3326	7.58[a]	1000000
OZONE GENERATOR					
9212	1	$ 323078	$ 739410	1[b]	1000000
COOLER-CHILLER					
9221	1	$ 5000	$ 2000	1[b]	1[b]

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

STUDY CONDUCTED BY VINCENT J CICCONE SEPTEMBER 23 1981

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding

COMPUTER OUTPUT 3.1.3.4b

PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON:THERMAL REGENERATION (0.652 LBS TNT/LB)
WITH TREATMENT B (ULTRAVIOLET-OZONE (8 LAMPS/SQ.FT)).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 2510422 AND FOR ALTERNATIVE B = $ 3570436;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 1.42; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 1000000 GALLONS: SYSTEM B = 1000000 GALLONS

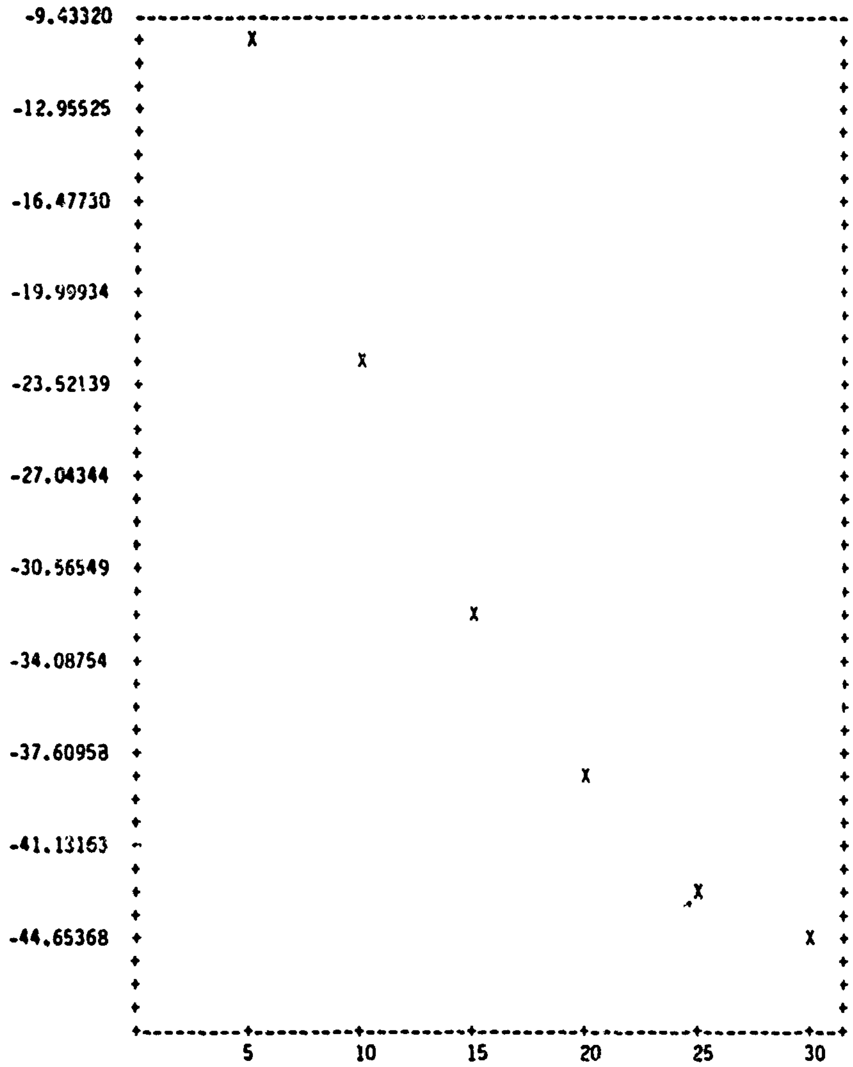
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	1022000	2981000	5798000	9401000	13723000	18706000
TOT. OP. COSTS FOR ALTERN. B $	13485000	39324000	76479000	123999000	181013000	246726000
CURRENT SALVAGE VALUE FOR A $	2092000	1673000	1255000	836000	418000	-1000
CURRENT SALVAGE VALUE FOR B $	2975000	2380000	1785000	1190000	595000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	.58925	.23437	.08739	.02896	.00720	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	1750	3500	5250	7000	8750	10500
TOT. FLOW (MGAL) FOR ALTERN B	1750	3500	5250	7000	8750	10500
RSUM FOR ALTERNATIVE A	0.75366	1.77567	2.57859	3.11204	3.43341	3.62852
RSUM FOR ALTERNATIVE B	9.94056	23.42059	34.01086	41.04692	45.35155	47.85900
*THE DISCRIMINANT IS	-9.4342	-21.9975	-31.8285	-38.3485	-42.3332	-44.6527
PVUC ($/MGAL PROCESSED): A $	820	790	770	750	730	710
PVUC ($/MGAL PROCESSED): B $	8000	7700	7400	7100	6800	6500

****

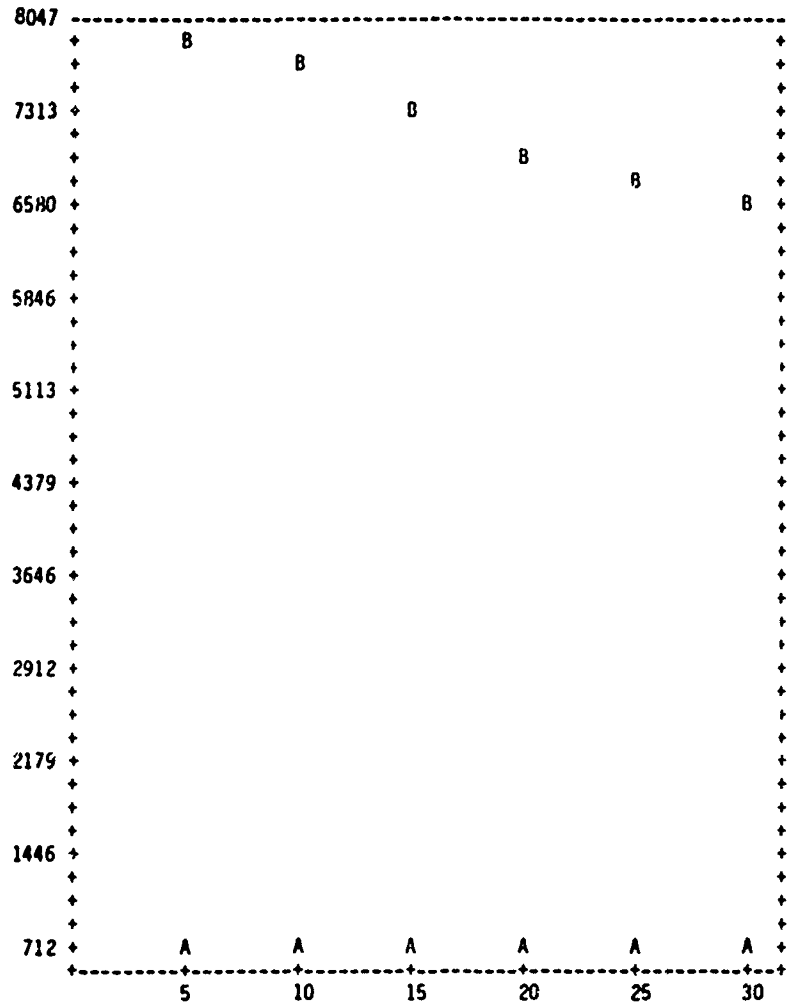
STUDY CONDUCTED BY VINCENT J CICCONE SEPTEMBER 23 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON:THERMAL REGENERATION (0.652 LBS TNT/LB AND SYSTEM (B):
ULTRAVIOLET-OZONE (8 LAMPS/SQ.FT)
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY VINCENT J CICCONE　　　　SEPTEMBER 23 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON:THERMAL REGENERATION (0.652 LBS TNT/LB AND SYSTEM (B):
ULTRAVIOLET-OZONE (8 LAMPS/SQ.FT)
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY VINCENT J CICCONE SEPTEMBER 23 1981

COMPUTER OUTPUT 3.1.3.5b

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)[6]

WITH SYSTEM (B): LIQUID-LIQUID EXTRACTION

FOR FLOW RATE OF 1 000 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 30, 1981

COMPUTER OUTPUT 3.1.3.5b

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS
INDICATED OTHERWISE IN THE BODY OF THE TABLE. THE
LIFE SPAN FOR ALL UNITS IS SET AT 30 YEARS AND THE
FLOW IS 1 000 000 GPD.

ALTERNATIVE (A)
CARBON: THERMAL REGEN. (0.652 LBS INI/LB C)

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58^a	1000000
EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	[illegible]
PUMP-PRESS. EQUALIZATION					
9206	2	$ 1047	$ 1737	2.66^a	1000000
MIXED MEDIA PRESS. FILT.					
9239	4	$ 113523	$ 460	5000	340000
CARBON COLUMN WITH THERMAL REG					
9219	1	$ 359106	$ 47821	21000	1000000
CONVEYOR SCREW					
9231	3	$ 4566	$ 2000	1^b	25^c
WASTE CARBON TNK-STL OR MI					
9214	3	$ 7612	$ 0	25000	10000
CARBON REGEN FURNACE					
9211	1	$ 1339783	$ 147598	1^b	300^d
CARBON DE-FINE TANK					
9240	1	$ 140852	$ 2000	25000	25000
HOLDING TANK					
9223	1	$ 7612	$ 0	25000	1000000

ALTERNATIVE (B)
LIQUID - LIQUID EXTRACTION

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58^a	1000000
EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION					
9206	3	$ 1047	$ 1737	2.66^a	1000000
MIXED MEDIA PRESS. FILT.					
9239	4	$ 113523	$ 460	5000	340000
SOLVENT EXTRACTION					
9245	4	$ 5323248	$ 3018722	60000	8^f
SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000
FRACTIONAL DISTILLATION					
9246	1	$ 2433326	$ 420390	12.9^f	1000000
SURF. STR/MIX/BODY FEED TNK					
9224	2	$ 1361	$ 0	500	0^b
CHEMICAL FEEDER					
9225	2	$ 3000	$ 1000	1^b	1^b
HOLDING TANK					
9223	1	$ 7612	$ 0	25000	1000000

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet
f = ten thousand pounds per day

PUMP-PRESS. BACKWASH						!	PUMP-PRESS. BACKWASH						
9204	1	$ 3700	$ 83	31.6[a]	100000	!	9204	1	$ 3700	$ 83	31.6[a]	100000	
VIRGIN CARBON STORAGE TANK						!							
9208	1	$ 7709	$ 0	24000	24000	!							

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

NOTE: Not all values shown relate to column headings.
a = hydraulic horsepower

COMPUTER OUTPUT 3.1.3.5b
PRESENT VALUE UNIT COST ANALYSIS
COMPARING TREATMENT A (CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C))
WITH TREATMENT B (LIQUID - LIQUID EXTRACTION).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 2510422 AND FOR ALTERNATIVE B = $24381527;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 9.71; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 1000000 GALLONS: SYSTEM B = 1000000 GALLONS

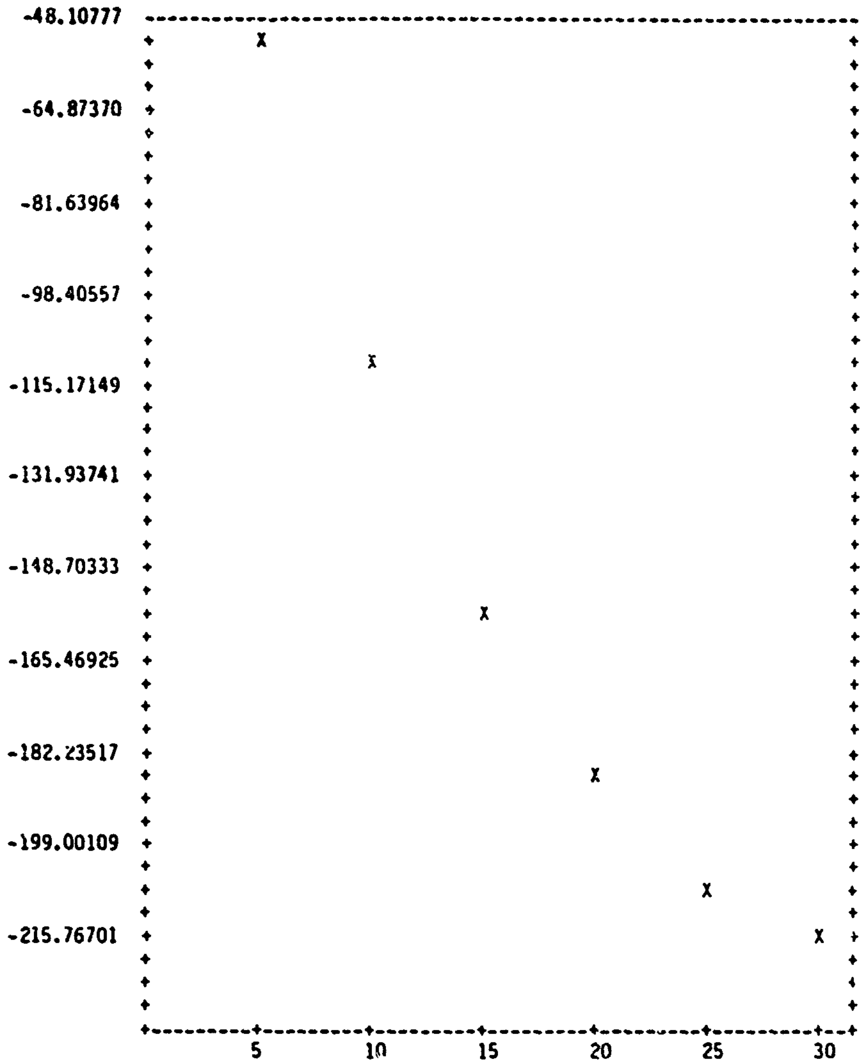
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	1022000	2981000	5798000	9401000	13723000	18706000
TOT. OP. COSTS FOR ALTERN. B $	59366000	173113000	336673000	545863000	796850000	?????????
CURRENT SALVAGE VALUE FOR A $	2092000	1673000	1255000	836000	418000	-1000
CURRENT SALVAGE VALUE FOR B $	20317000	16254000	12190000	8127000	4063000	-1000
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	4.02386	1.60045	.59678	.19780	.04917	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	1750	3500	5250	7000	8750	10500
TOT. FLOW (MGAL) FOR ALTERN B	1750	3500	5250	7000	8750	10500
RSUM FOR ALTERNATIVE A	0.75366	1.77567	2.57859	3.11204	3.43841	3.62852
RSUM FOR ALTERNATIVE B	43.75987	????????	????????	????????	????????	????????
*THE DISCRIMINANT IS	-48.1087	????????	????????	????????	????????	????????
PVUC ($/MGAL PROCESSED): A $	820	790	770	750	730	710
PVUC ($/MGAL PROCESSED): B $	36200	34800	33400	32200	31000	29800

****

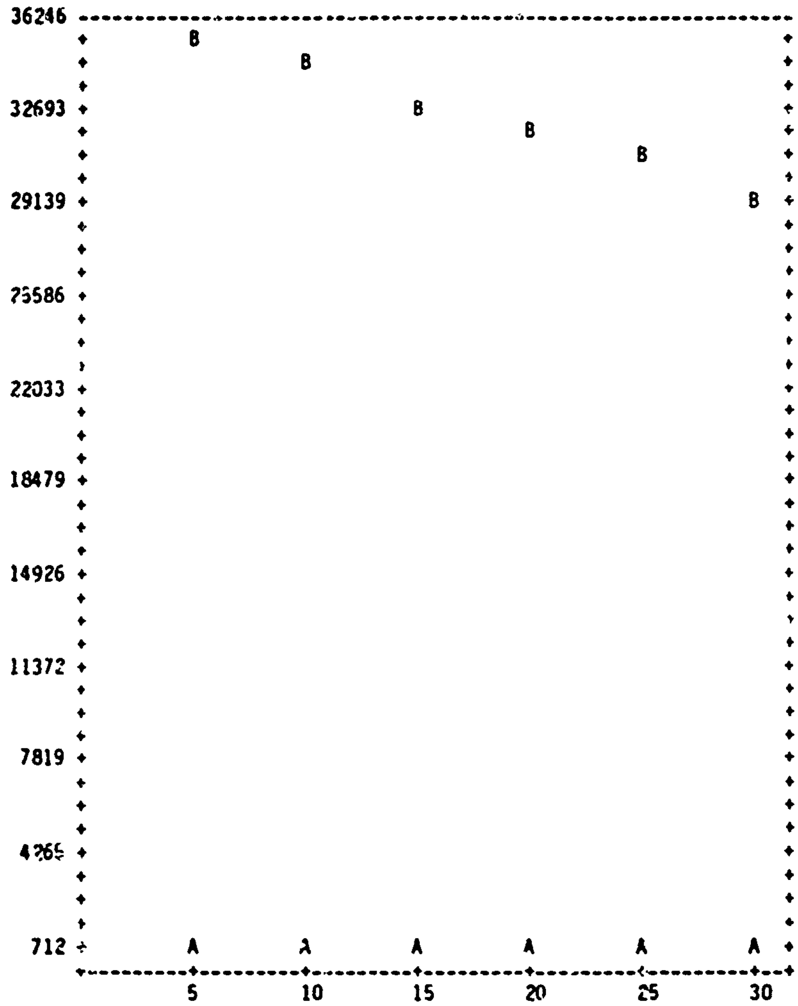
STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B".
Here values have exceeded the capacity of the computer.



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
LIQUID - LIQUID EXTRACTION
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
LIQUID - LIQUID EXTRACTION
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

COMPUTER OUTPUT 3.1.3.6b

SUMMARY OF PVUC ANALYSIS COMPARING

SYSTEM (A): CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C)(6)

WITH SYSTEM (B): ULTRAFILTRATION

FOR FLOW RATE OF 1 000 000 GPD

BY

GEORGE A. GARRIGAN

SEPTEMBER 10, 1981

COMPUTER OUTPUT 3.1.3.6b

LISTING OF ALL COMPONENTS FOR PVUC STUDY.
BASELINE FOR ALL COSTS IS DECEMBER, 1980 UNLESS INDICATED OTHERWISE IN THE BODY OF THE TABLE. THE LIFE SPAN FOR ALL UNITS IS SET AT 30 YEARS AND THE FLOW IS 1 000 000 GPD.

ALTERNATIVE (A)
CARBON: THERMAL REGEN. (0.652 LBS INT/LB C)

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000
PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION					
9206	2	$ 1047	$ 1737	2.66[a]	1000000
MIXED MEDIA PRESS. FILT.					
9239	4	$ 113523	$ 460	5000	340000
CARBON COLUMN WITH THERMAL REG					
9219	1	$ 359106	$ 47821	21000	1000000
CONVEYOR SCREW					
9231	3	$ 4566	$ 2000	1[b]	25[c]
WASTE CARBON TNK-STL OR MI					
9214	3	$ 7612	$ 0	25000	10000
CARBON REGEN FURNACE					
9211	1	$ 1339783	$ 147598	1[b]	300[d]
CARBON DE-FINE TANK					
9240	1	$ 140852	$ 2000	25000	25000
HOLDING TANK					
9223	1	$ 7612	$ 0	25000	1000000

ALTERNATIVE (B)
ULTRAFILTRATION

NAME OF UNIT UNDERWRITTEN BY: CAT NO.	NOS. UNIT	UNIT CAP COST	UNIT O&M COST	CAPACTY (GAL)	UNIT GPD
SUMP-STL OR MI					
9228	1	$ 19006	$ 0	200000	1000000
HOLDING TANK					
9223	1	$ 7612	$ 0	25000	1000000
PUMP-PRESS. SUMP					
9207	2	$ 1786	$ 3326	7.58[a]	1000000
EQUALIZATION/SEDIMENTATION TAN					
9218	2	$ 68176	$ 0	1000000	1000000
PUMP-PRESS. EQUALIZATION					
9206	2	$ 1047	$ 1737	2.66[a]	1000000
MIXED MEDIA PRESS. FILT.					
9239	4	$ 113523	$ 460	5000	340000
UF MEMBRANE MODULE					
9227	100	$ 1513889	$ 219239	.1[g]	0[b]
PUMP-PRESS. BACKWASH					
9204	1	$ 3700	$ 83	31.6[a]	100000
UF-RECIRC. PUMP					
9226	100	$ 5774	$ 13844	75.6[a]	4320000

--CONTINUED

NOTE: Not all values shown relate to column headings.

a = hydraulic horsepower
b = BASIC coding
c = length in feet
d = square feet
g = million gallons per day

PUMP-PRESS. BACKWASH						
9204	1	$ 3700	$ 83	31.6[a]	100000	
VIRGIN CARBON STORAGE TANK						
9208	1	$ 7709	$ 0	24000	24000	

***** NOTE: ALL VALUES ROUNDED TO NEAREST INTEGER *****

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

NOTE: Not all values shown relate to column headings,
a = hydraulic horsepower

COMPUTER OUTPUT 3.1.3.6b

PRESENT VALUE UNIT COST ANALYSIS

COMPARING TREATMENT A (CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C))
WITH TREATMENT B (ULTRAFILTRATION).
SYSTEM LIFESPAN TO BE 30 YEARS WITH 350 OP. DAYS PER YEAR.
ANALYSES ARE OVER FIVE YEAR SPANS (OR 'HORIZONS').

TOTAL CAPITAL COSTS FOR ALTERNATIVE A = $ 2510422 AND FOR ALTERNATIVE B = $????????;
RATIO OF CAPITAL COSTS OF B TO CAPITAL COSTS OF A = 60.78; INTEREST RATE = .15;
INFLATION RATE = .13; FLOW RATIO OF A TO B ('ALPHA') = 1.0000
DAILY FLOW IN SYSTEM A = 1000000 GALLONS: SYSTEM B = 1000000 GALLONS

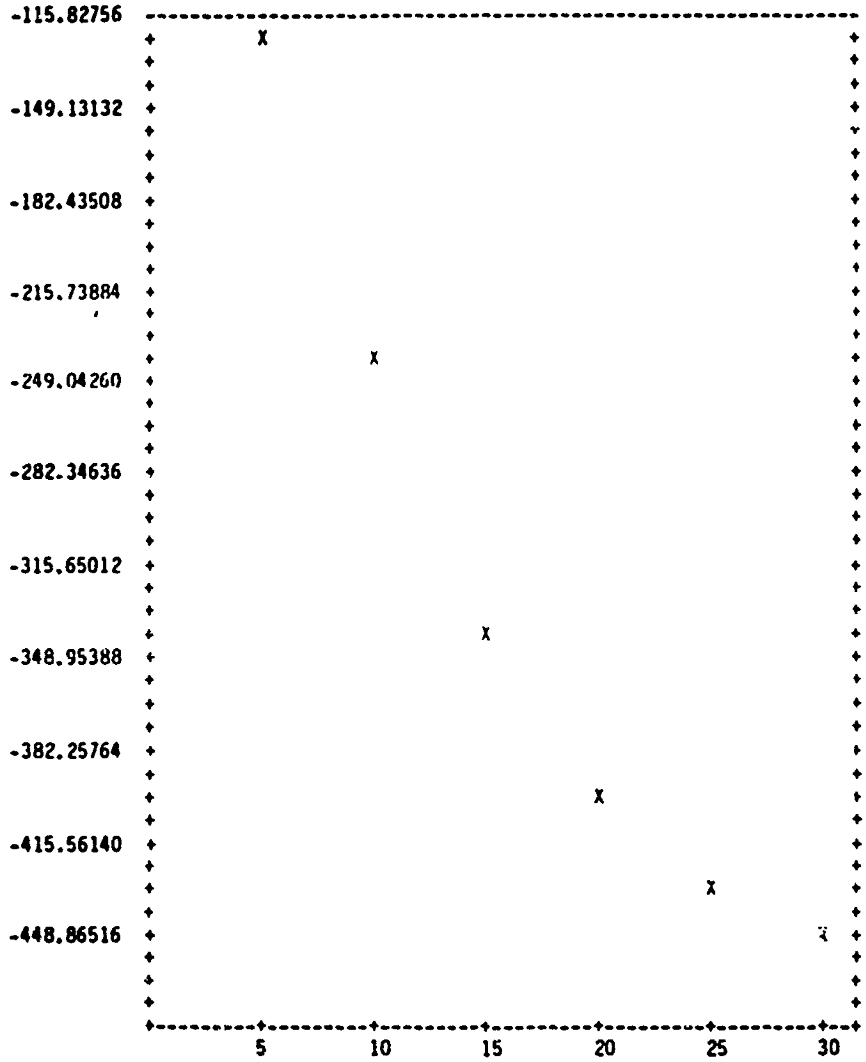
****

VALUES USED FOR DECISION PROCESS	TOTAL YR 1 TO 5	TOTAL YR 1 TO 10	TOTAL YR 1 TO 15	TOTAL YR 1 TO 20	TOTAL YR 1 TO 25	TOTAL YR 1 TO 30
TOT. OP. COSTS FOR ALTERN. A $	1022000	2981000	5798000	9401000	13723000	18706000
TOT. OP. COSTS FOR ALTERN. B $	110657000	322680000	627553000	?????????	?????????	?????????
CURRENT SALVAGE VALUE FOR A $	2092000	1673000	1255000	836000	418000	-1000
CURRENT SALVAGE VALUE FOR B $	127160000	101728000	76296000	50864000	25432000	0
SLVG PER DISCNT CAP. (THETA-A)	.41431	.16478	.06144	.02036	.00506	< 10E-5
SLVG PER DISCNT CAP. (THETA-B)	25.18353	10.01653	3.73499	1.23796	.30774	< 10E-5
TOT. FLOW (MGAL) FOR ALTERN A	1750	3500	5250	7000	8750	10500
TOT. FLOW (MGAL) FOR ALTERN B	1750	3500	5250	7000	8750	10500
RSUM FOR ALTERNATIVE A	0.75366	1.77567	2.57859	3.11204	3.43841	3.62852
RSUM FOR ALTERNATIVE B	81.56774	????????	????????	????????	????????	????????
*THE DISCRIMINANT IS	????????	????????	????????	????????	????????	????????
PVUC ($/MGAL PROCESSED): A $	820	790	770	750	730	710
PVUC ($/MGAL PROCESSED): B $	77700	75100	72600	70200	67900	65800

****

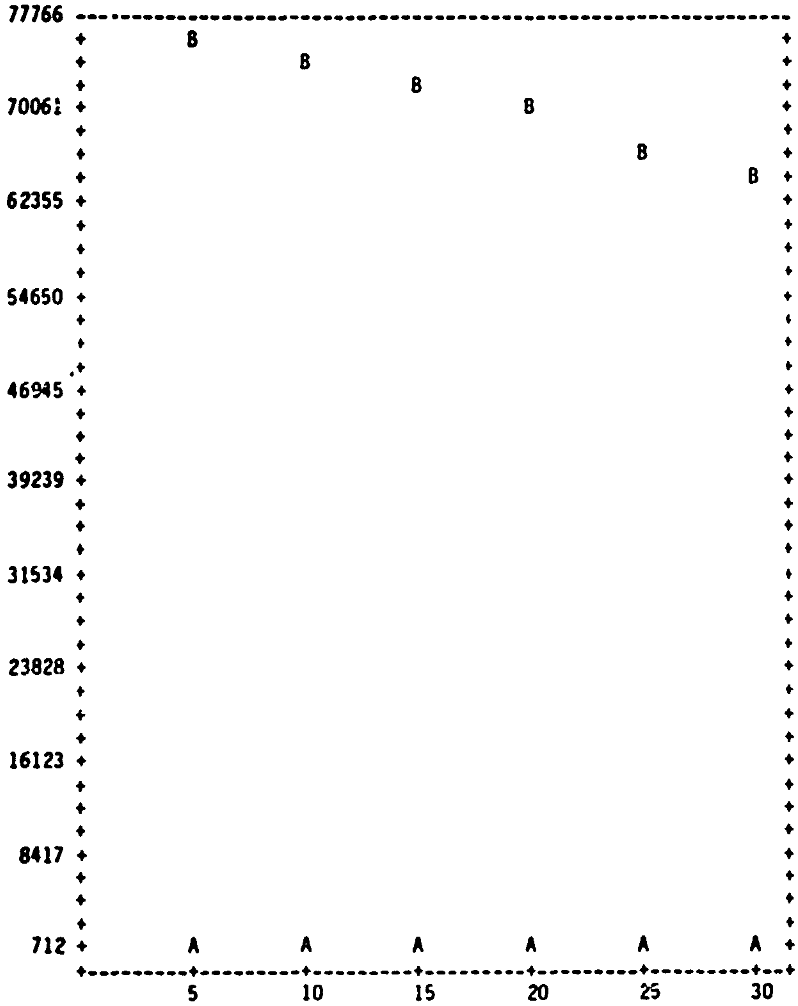
STUDY CONDUCTED BY GEORGE A. GARRIGAN — SEPTEMBER 10 1981

* The "Discriminant" is the normalized difference between PVUC "A" and PVUC "B". Here the value has exceeded the capacity of the computer.



DISCRIMINANT VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
ULTRAFILTRATION
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981



PVUC $/MGAL PROCESSED VS YEARS FOR SYSTEM (A):
CARBON: THERMAL REGEN. (0.652 LBS TNT/LB C) AND SYSTEM (B):
ULTRAFILTRATION
FOR FLOW OF 1 000 000 GPD.

STUDY CONDUCTED BY GEORGE A. GARRIGAN SEPTEMBER 10 1981

3.1.4 Table 3.2 presents a compilation of the calculated capital and annual operating costs for each of the seven treatment technologies. It indicates those systems that are either capital or operating intensive and provides a quick reference for making gross comparisons. Tables 3.3 and 3.4 represent the calculated PVUC's of the alternatives, for each of the specified daily flows, given an anticipated thrity-year system life. The unit costs are for five-year interval time horizons, and are expressed as present value dollars per thousand gallons of pink water treated ($/K-GAL).

These PVUC values were calculated on a yearly basis and reported at the five-year intervals. They are the outputs produced by the computer simulations which compared the treatment alternatives according to the schedule shown in Table 3.1. The discount factor and inflation rate used were 15 percent and 13 percent respectively. These are reasonable assumptions based upon figures reported by the Federal Government for 1980 as discussed in Section 2.8.2

Figures 3.1 and 3.2 are the graphical representations of the calculated costs tabluated in Tables 3.3 and 3.4. These diagrams clearly show a distinct breakpoint of the calculated costs into those below $7.00/K-GAL and those above $10.00/K-GAL. The breakpoint is so apparent that it immediately suggests how expensive ultrafiltration and liquid/liquid extraction are as compared to the other technologies under consideration.

3.1.5 In order to provide a convenient means to tabulate the calculated PVUC values for each of the alternative schemes, Tables 3.5 and 3.6 were constructed. These matrices, which list the alternative schemes in both the columns and rows, show not only the combinations of comparisons examined but also the calculated PVUC values (as the elements of the matrix) for the first five-year horizon.

3.1.6 A "Discriminant", which is the normalized indicator showing whether, for any given horizon, one alternative is less or more expensive than a competitive alternative, was calculated and listed as an output in the computer simulations or runs. Subsequently, Tables 3.7 and 3.8 were constructed to tabulate the results comparing the six other alternatives to Granular Carbon Adsorption with Thermal Regeneration. These tables show a range of anticipated dollar savings by using the Granular Carbon Adsorption with Thermal Regeneration alternative

	Ultrafiltration	Liquid / Liquid Extraction	UV-Ozone	Powdered Carbon w/AST Regen.	Surfactant Complexing	Granular Carbon w/ No Regen.	Granular Carbon w/Thermal Regen.
100,000 GPD							
Capital Costs	15,311,815	2,750,668	623,380	669,416	136,445	307,750	974,080
Average Annual O & M Costs (Based on first 5-year horizon)	2,223,200	1,575,200	309,480	148,000	139,400	88,800	47,000
1,000,000 GPD							
Capital Costs	$>10^8$	24,381,527	3,570,436	3,033,189	488,588	1,029,786	2,510,422
Average Annual O & M Costs (Based on first 5-year horizon)	2,213,140	11,873,200	2,697,000	931,600	1,279,800	727,200	204,400

TABLE 3.2

CALCULATED CAPITAL & ANNUAL OPERATING COSTS FOR EACH ALTERNATIVE CONSIDERED

TIME HORIZON (Years)	Granular Carbon w/ Thermal Regen.	Granular Carbon w/ No Regen.	Surfactant Complexing	Powdered Carbon w/ AST Regen.	UV–Ozone	Liquid/Liquid Extraction	Ultrafiltration
5	2.20	2.80	4.10	4.80	9.40	47.60	78.10
10	2.20	2.70	3.90	4.60	9.00	45.70	75.40
15	2.10	2.60	3.70	4.50	8.70	43.90	72.90
20	2.10	2.50	3.60	4.30	8.30	42.20	70.50
25	2.00	2.40	3.40	4.20	8.00	40.60	68.30
30	2.00	2.30	3.30	4.00	7.70	39.10	66.10

TABLE 3.3

CALCULATED PVUC ($/K-GAL) FOR EACH ALTERNATIVE

30-Year Planning Horizon

100,000 GPD

TIME HORIZON (Years)	Granular Carbon w/ Thermal Regen.	Granular Carbon w/ No Regen.	Surfactant Complexing	Powdered Carbon w/ AST Regen.	UV-Ozone	Liquid/Liquid Extraction	Ultrafiltration
5	0.82	2.10	3.70	2.90	8.00	36.20	77.70
10	0.79	2.00	3.50	2.80	7.70	34.80	75.10
15	0.77	2.00	3.40	2.70	7.40	33.40	72.60
20	0.75	1.90	3.20	2.60	7.10	32.20	70.20
25	0.73	1.80	3.10	2.50	6.80	31.00	67.90
30	0.71	1.70	3.00	2.40	6.50	29.80	65.80

TABLE 3.4

CALCULATED PVUC ($/K-GAL) FOR EACH ALTERNATIVE

30-Year Planning Horizon

1,000,000 GPD

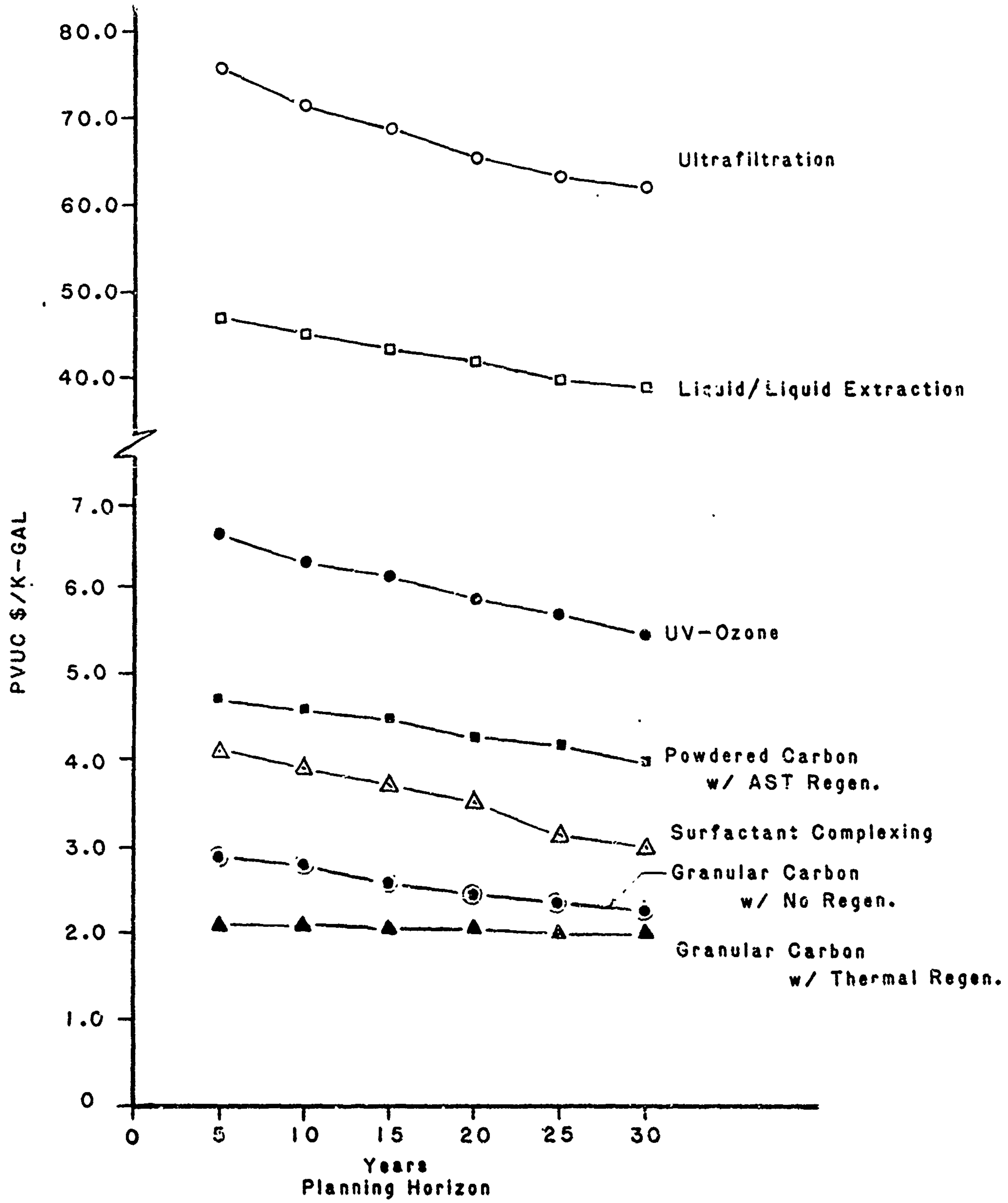


FIGURE 3.1

CALCULATED PVUC ($/K-GAL) FOR EACH ALTERNATIVE VS PLANNING HORIZONS

100,000 GPD

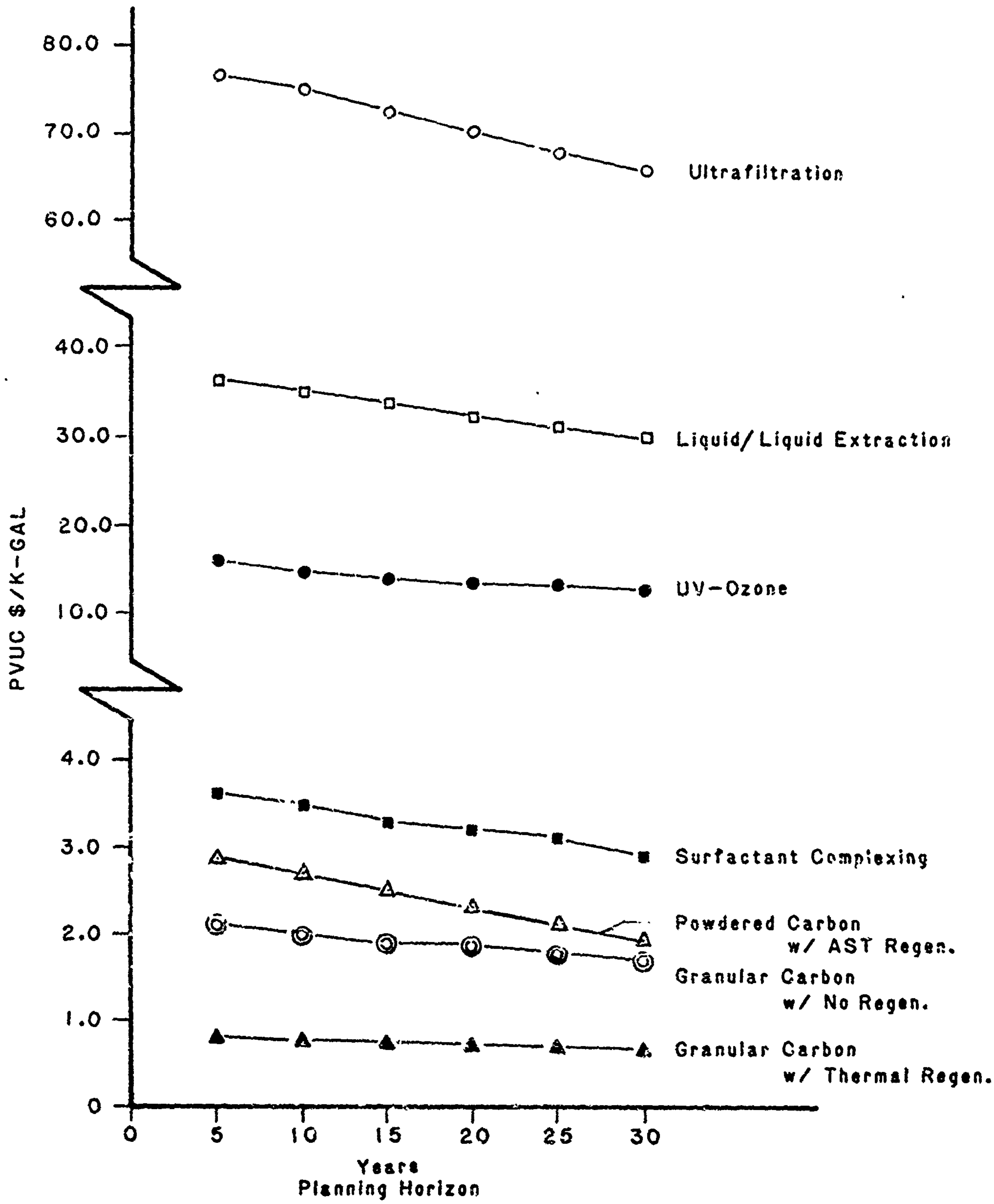


FIGURE 3.2

CALCULATED PVUC ($/K-GAL) FOR EACH ALTERNATIVE VS PLANNING HORIZONS

1,000,000 GPD

	Alternative "B" \ Alternative "A"	Granular Carbon w/ Thermal Regen.	Granular Carbon w/ No Regen.	Surfactant Complexing	Powdered Carbon w/ AST Regen.	UV-Ozone	Liquid/Liquid Extraction	Ultrafiltration
1	Granular Carbon w/ Thermal Regen.		A= 2.80 B= 2.20	A= 4.10 B= 2.20	A= 4.80 B= 2.20	A= 9.40 B= 2.20	A=47.60 B- 2.20	A=78.60 B= 2.20
2	Granular Carbon w/ No Regen.	A= 2.20 B= 2.80		A= 4.10 B= 2.80	A= 4.80 B= 2.80	A= 9.40 B= 2.80	A=47.60 B= 2.80	A=78.60 B= 2.80
3	Surfactant Complexing	A= 2.20 B= 4.10	A= 2.80 B= 4.10		A= 4.80 B= 4.10	A= 9.40 B= 4.10	A=47.60 B= 4.10	A=78.60 B= 4.10
4	Powdered Carbon w/ AST Regen.	A= 2.20 B= 4.80	A= 2.80 B= 4.80	A= 4.10 B= 4.80		A= 9.40 B= 4.80	A=47.60 B= 4.80	A=78.60 B= 4.80
5	UV- Ozone	A= 2.20 B= 9.40	A= 2.80 B= 9.40	A= 4.10 B= 9.40	A= 4.80 B= 9.40		A=47.60 B= 9.40	A=78.60 B= 9.40
6	Liquid/Liquid Extraction	A= 2.20 B=47.60	A= 2.80 B=47.60	A= 4.10 B=47.60	A= 4.80 B=47.60	A= 9.40 B=47.60		A=78.60 B=47.60
7	Ultrafiltration	A= 2.20 B=78.60	A= 2.80 B=78.60	A= 4.10 B=78.60	A= 4.80 B=78.60	A= 9.40 B=78.60	A=47.60 B=78.60	

TABLE 3.5

CALCULATED PVUC ($/K-GAL) FOR EACH ALTERNATIVE

5-Year Horizon
100,000 GPD

	Alternative "B" \ Alternative "A"	Granular Carbon w/ Thermal Regen.	Granular Carbon w/ No Regen.	Surfactant Complexing	Powdered Carbon w/ AST Regen.	UV-Ozone	Liquid/Liquid Extraction	Ultrafiltration
1	Granular Carbon w/ Thermal Regen.		A= 2.10 B= 0.82	A= 3.70 B= 0.82	A= 2.90 B= 0.82	A= 8.00 B= 0.82	A=36.20 B= 0.82	A=77.70 B= 0.82
2	Granular Carbon w/ No Regen.	A= 0.82 B= 2.10		A= 3.70 B= 2.10	A= 2.90 B= 2.10	A= 8.00 B=2.10	A=36.20 B= 2.10	A=77.70 B= 2.10
3	Surfactant Complexing	A= 0.82 B= 3.70	A= 2.10 B= 3.70		A- 2.90 B= 3.70	A= 8.00 B= 3.70	A=36.20 B= 3.70	A=77.70 B= 3.70
4	Powdered Carbon w/ AST Regen.	A= 0.82 B= 2.90	A= 2.10 B= 2.90	A- 3.70 B= 2.90		A= 8.00 B= 2.90	A=36.20 B= 2.90	A=77.70 B= 2.90
5	UV-Ozone	A= 0.82 B= 8.00	A= 2.10 B= 8.00	A- 3.70 B= 8.00	A= 2.90 B= 8.00		A=36.20 B= 8.00	A=77.70 B= 8.00
6	Liquid/Liquid Extraction	A= 0.82 B=36.20	A= 2.10 B=36.20	A= 3.70 B=36.20	A= 2.90 B=36.20	A= 8.00 B=36.20		A=77.70 B=36.20
7	Ultrafiltration	A= 0.82 B=77.70	A= 2.10 B=77.70	A= 3.70 B=77.70	A= 2.90 B=77.70	A= 8.00 B=77.70	A=36.20 B=77.70	

TABLE 3.6

CALCULATED PVUC ($/K-GAL) FOR EACH ALTERNATIVE

5-Year Horizon

1,000,000 GPD

Alternative Scheme	Year	PVUC $/KGal	Discriminant	Savings Over Horizon $ (Savings = Cap.S(A) x Disc)	Annual Savings $ (Annual Savings = Savings/Yrs.)
Granular Carbon w/ Thermal Regen.	5	2.20			
	10	2.20			
	15	2.10			
	20	2.10			
	25	2.00			
	30	2.00			
Granular Carbon w/ No Regen.	5	2.80	- 0.0083	8,084	1,617
	10	2.70	- 1.1596	1,129,543	112,954
	15	2.60	- 2.2779	2,218,857	147,924
	20	2.50	- 3.0806	3,000,750	150,038
	25	2.40	- 3.5930	3,499,869	139,995
	30	2.30	- 3.8998	3,798,717	126,624
Surfactant Complexing	5	4.10	- 0.3738	364,111	72,822
	10	3.90	- 1.3492	1,314,229	131,423
	15	3.70	- 2.1952	2,138,300	142,553
	20	3.60	- 2.7809	2,708,819	135,441
	25	3.40	- 3.1478	3,066,209	122,648
	30	3.30	- 3.3647	3,277,487	109,250
Powdered Carbon w/ AST Regen.	5	5.50	- 0.7766	756,471	151,294
	10	5.30	- 2.0002	1,948,355	194,836
	15	5.10	- 2.9905	2,912,986	194,199
	20	5.00	- 3.6571	3,562,308	178,115
	25	4.80	- 4.0679	3,962,460	158,498
	30	4.70	- 4.3085	4,196,824	139,894
UV-Ozone	5	9.40	- 2.2817	2,222,558	444,512
	10	9.10	- 5.5721	5,427,671	542,767
	15	8.70	- 8.1905	7,978,202	531,880
	20	8.30	- 9.9400	9,682,355	484,118
	25	8.00	-11.0139	10,728,420	429,137
	30	7.70	-11.6409	11,339,168	377,972
Liquid/Liquid Extraction	5	47.60	-15.5841	15,180,160	3,036,032
	10	45.70	-35.7237	34,797,742	3,479,774
	15	43.90	-51.3769	50,045,211	3,336,374
	20	42.20	-61.7264	60,126,452	3,006,323
	25	40.60	-68.0403	66,276,695	2,651,068
	30	39.10	-71.7110	69,852,251	2,328,408
Ultrafiltration	5	78.10	-29.3042	28,544,635	5,708,927
	10	75.40	-61.0137	59,432,225	5,943,223
	15	72.90	-84.5593	82,367,523	5,491,168
	20	70.50	-99.7963	97,209,580	4,860,479
	25	68.30	EXCEEDED CAPACITY OF PROGRAMMED PRINTOUT		
	30	66.10			

TABLE 3.7
CALCULATED ANNUAL SAVINGS BY USING GRANULAR CARBON
WITH THERMAL REGENERATION
100,000 GPD

Alternative Scheme	Year	PVUC $/KGal	Discriminant	Savings Over Horizon $ Savings = Cap. $(A) x Disc	Annual Savings $ Annual Savings= Savings/Years
Granular Carbon w/ Thermal Regen.	5	0.82			
	10	0.79			
	15	0.77			
	20	0.75			
	25	0.73			
	30	0.71			
Granular Carbon w/ No Regen.	5	2.10	- 3.8543	9,675,920	1,935,184
	10	2.00	- 9.8643	24,763,556	2,476,356
	15	2.00	-14.7191	36.951,152	2,463,410
	20	1.90	-17.9843	45,148,182	2,257,409
	25	1.80	-19.9960	50,198,398	2,007.936
	30	1.70	-21.1734	53,154,169	1,771.806
Surfactant Complexing	5	3.70	- 3.4918	8,765,892	1,753,178
	10	3.50	- 8.6657	21,754,564	2,175,456
	15	3.40	-12.8051	32,146,205	2,143,080
	20	3.20	-15.5775	39,106,099	1,955,305
	25	3.10	-17.2816	43,384,109	1,735,364
	30	3.00	-18.2773	45,883,736	1,529,458
Powdered Carbon w/ AST Regen.	5	2.90	- 2.8023	7,034,956	1,406,991
	10	2.80	- 6.4891	16,290,379	1,629,038
	15	2.70	- 9.3663	23,513,366	1,567,558
	20	2.60	-11.2720	28,297,477	1,414,874
	25	2.50	-12.4359	31,219,357	1,248,774
	30	2.40	-13.1131	32,919,415	1,097.314
UV-Ozone	5	8.20	- 9.4342	23,683.823	4,736,765
	10	7.90	-21.9975	55,223,008	5,522,301
	15	7.60	-31.8285	79.902,967	5,326,865
	20	7.30	-38.3485	96,270,918	4,813,546
	25	7.00	-42.3332	106,274,197	4,250,968
	30	6.70	-44.6527	112,097,120	3,736.571
Liquid/ Liquid Extraction	5	36.20	-48.1087	371,820,000	74,364,000
	10	34.80	EXCEEDED CAPACITY OF PROGRAMMED PRINTOUT		
	15	33.40			
	20	32.20			
	25	31.00			
	30	29.80			
Ultrafiltration	5	77.70	EXCEEDED CAPACITY OF PROGRAMMED PRINTOUT		
	10	75.10			
	15	72.60			
	20	70.20			
	25	67.90			
	30	65.80			

TABLE 3.8.

CALCULATED ANNUAL SAVINGS BY USING GRANULAR CARBON WITH THERMAL REGENERATION 1,000,000 GPD

over the others. Specifically, Table 3.7 shows that if the granular carbon with thermal regeneration treatment scheme is selected over the granular carbon with no regeneration scheme (for 10^5 GPD), then a predicted annual savings over the first five-year horizon is \$8,084 and for the ten-year horizon it is \$1,129,543, and so forth. Similar comparisons and calculated annual savings predictions are shown in Tables 3.7 and 3.8 for the other alternative pink water treatment schemes for both the 10^5 and 10^6 GPD flows.

3.1.7 As is to be expected in comparing a series of wastewater treatment methods on a unit cost basis, there will be the most economical methods, the least economical methods, and the other treatment techniques will fall somewhere in between the two extremes. The two granular carbon adsorption techniques, with and without regeneration, were the most economically favorable methods found in this study. The two least economically favorable methods were found to be liquid/liquid extraction and ultrafiltration. The powdered carbon with AST regeneration method, the surfactant complexing method and the UV-Ozone method fell between the cost extremes. See Figure 3.2.

The high treatment unit cost of ultrafiltration is caused by its inefficiency in removing the low molecular weight constituent in pink wastewater. The high unit cost is reflected in both the capital investment for the series of ultrafiltration membrane modules and the high annual power requirements for recirculation pumping. The relatively high lqiuid/liquid extraction unit costs are mainly influenced by the capital costs for fractional distillation equipment and for solvent extraction columns; operation and maintenance expenditures for the solvent extraction columns are also estimated to be high.

For the middle cost range methods, UV-Ozone costs are influenced by the capital cost of the ozone reactor plus the purchase cost of the ozone generator. The high operation and maintenance costs are reflected in the annual requirement to replace a large number of UV lamps plus the cost of electrical power to operate the lamps continuously. The ultrafiltration method and the UV-Ozone method are the most power intensive treatment techniques. The operation cost of the ozone generator is also considerable.

The largest capital investment for surfactant complexing is for the vacuum filter, and this method's highest operation and maintenance costs arise from the amount and concentration of surfactant introduced constantly into the surfactant reaction tanks. An additional significant operation and maintenance factor is the cost of acid neutralization of the surfactant treated alkaline wastewaters.

The main capital costs for the powdered carbon method are those for the AST furnace, the clarifiers and for the vacuum filters. The largest operation and maintenance costs are likewise expected to occur in the operation of the AST furnace, the clarifiers and the dry feed equipment.

The highest capital cost for granular carbon without regeneration is for the carbon column unit and that unit is expected to incur the largest operation and maintenance cost for carbon replacement on a once-used basis. The highest capital cost for granular carbon with regeneration is for the carbon furnace and it is in this unit that the highest operation and maintenance costs are expected to occur. The second highest capital outlay cost in the regeneration treatment method is for the carbon column unit which is expected to incur only modest annual operating costs.

The real economic advantage of granular carbon adsorption, both with and without regeneration, lies in relatively low average annual operation and maintenance costs compared to the other treatment methods. See Table 3.2. For instance, even though the 10^5 GPD plant total capital cost of granular carbon with regeneration is higher than the total capital cost of surfactant complexing or granular carbon without regeneration or powdered carbon with AST regeneration or UV-Ozone, the calculated low average annual operation and maintenance cost for granular carbon with regeneration makes it the most attractive of all pink wastewaer treatment methods studied on a unit cost basis.

3.2 SENSITIVITY ANALYSIS

Analysis and discussion of the findings presented in the above paragraphs yield sufficient information so that a rational "ranking" of the seven technologies could be made by engineering and management personnel directly concerned with the pink water problem. However, several significant operating and cost parameters are worthy of further analyses, especially because of their

respective impact upon decision parameters, namely, the PVUC and the discriminant. Analytical experiments were conducted to examine the "sensitivity" of these decision parameters to variations in selected significant factors, such as the adsorption rate for carbon (lbs of TNT/lb of carbon) or the number of ultraviolet lamps. The experimental results were obtained and discussion of those findings are presented below.

3.2.1 Sensitivity of the Granular Carbon With and Without Regeneration Alternatives to the Adsorption Rate of the Carbon.

The range of granular activated carbon adsorption rates reported in the literature and from on-site visits varies between 0.2 to 0.652 lbs TNT per lb of carbon available. For the purposes of this sensitivity analysis, 5 adsorption rate values ranging from 0.2 to 1.0 lb TNT per lb of carbon at intervals of 0.2 lb were selected. Calculations were made for each value to determine the frequency of replacing spent or exhausted carbon for a 350 day operational year, assuming all other factors remained as originally given. This information, in turn, was used to adjust the appropriate capital and operating cost functions associated with each of the carbon adsorption rates. Those values were then entered into the data sets of both the non-regeneration and thermal regeneration treatment schemes from which the PVUC values were calculated. Results of these computer experiments - for the first five-year horizon - are presented in Figure 3.2.1 for the specified daily flows of 10^5 and 10^6 GPD. Interpretation of Figure 3.2.1 indicates that the non-regenerative alternative is particularly sensitive to the TNT/carbon adsorption rate. It would appear to be a worthwhile venture to search for and develop a better or more efficient carbon in terms of the adsorption rate. Such research and development is appropriate to an adsorption rate of 0.6. Beyond that value, little gain in reduction of the treatment system unit costs appears feasible. However, in the range of 0.2 to 0.65, the estimated reduction from \$6.00/K-GAL at 0.2 to \$2.70/K-GAL at 0.65 for the 10^5 GPD flow and \$5.10/K-GAL to \$2.30/K-GAL for the 10^6 GPD flow is significant. The increased frequency of replacement and its associated disposal costs for the lower adsorption rate carbon, force the dramatic cost shifts. In general, the costs for non-regenerative carbon systems are best reduced through the

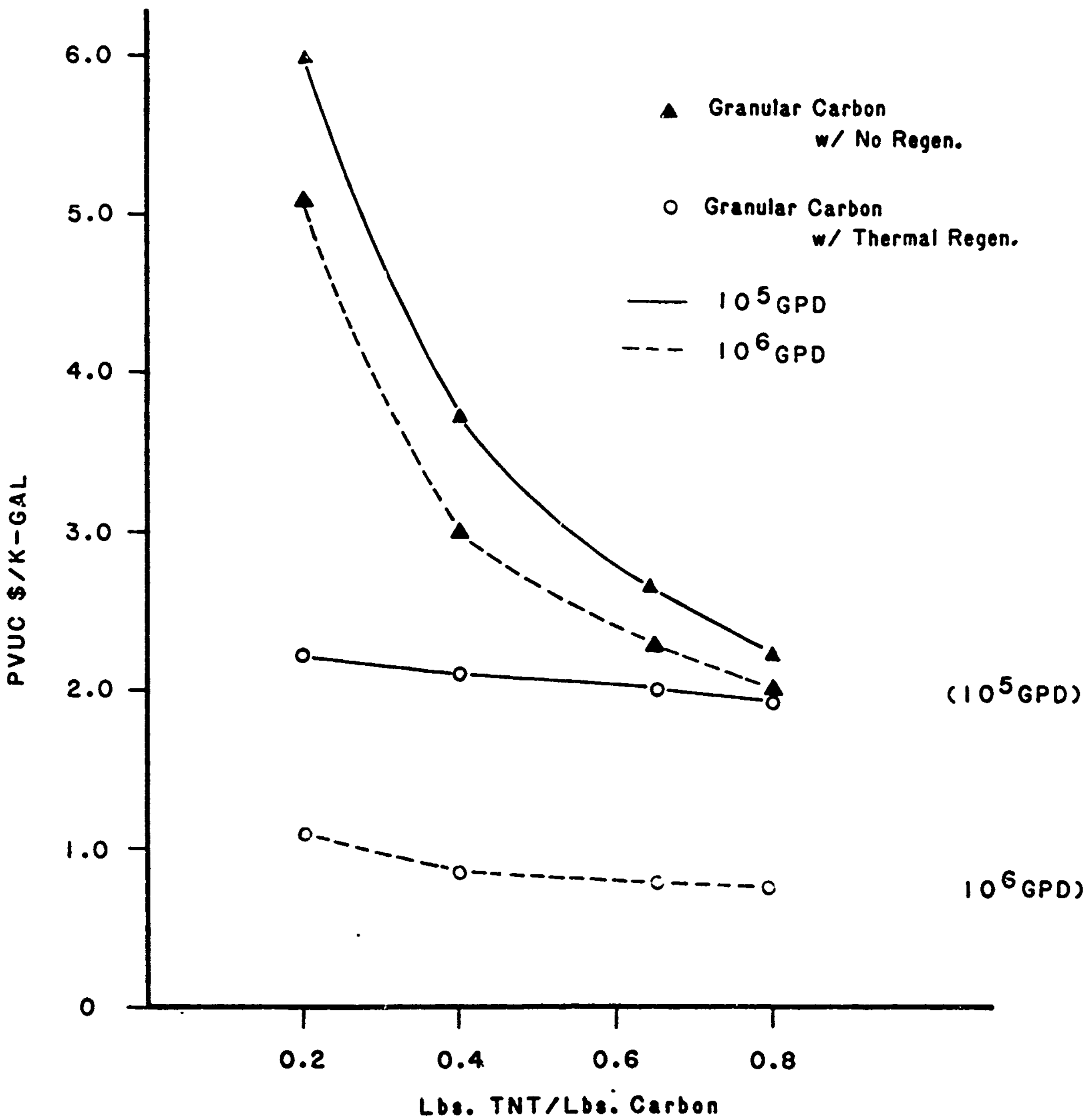


FIGURE 3.2.1

SENSITIVITY OF THE GRANULAR CARBON ALTERNATIVE TO THE ADSORPTION RATE OF CARBON

development and incorporation of higher adsorption rate carbon as might be expected. However, beyond 0.65 lb TNT/lb carbon little if any savings would be realized.

In the thermal regenerative carbon system, where virgin carbon replacement was held to approximately 10 percent per regenerative cycle, the calculated PVUC costs for the lowest adsorption rate carbon (0.2) is not much greater than the PVUC costs for the more efficient carbon (0.65). The flat slope of the curve over the range of adsorption rates indicates that substantial savings in system costs of operating the thermal carbon regeneration alternative are not to be found in the use of higher efficiency carbons but rather in other features, such as perhaps improved regenerative technology. Throughout the ranges studied, the carbon regenerative alternative was found to have a consistently lower calculated PVUC than the non-regenerative system. This held true for both daily flow rates considered. The difference was greatest with the lower adsorption rate carbons, i.e., approximately a 62 percent difference for carbons adsorbing about 0.2 lbs TNT/lb carbon at 10^5 GPD and about 75 percent at 10^6 GPD flows. Higher efficiency carbons decreased this difference to about 14 percent for carbons adsorbing about 1 lb TNT/lb carbon at 10^5 GPD and 58 percent for 10^6 GPD.

3.2.2 Sensitivity of the UV-Ozone Alternative to the Number of UV Lamps Compared with Granular Carbon with Thermal Regeneration.

One analytical experiment compared the calculated PVUC for the Granular Carbon With Thermal Regeneration alternative with the UV-Ozone alternative employing from 2 to 8 lamps per square foot of reactor surface area assuming the system efficiency remained constant. The results are presented in Figure 3.2.2 which presents the calculated outputs from the computer analysis for the first five-year horizon and flow rates of 10^5 and 10^6 GPD. For the Granular Carbon With Thermal Regeneration alternative, the calculated values shown are based upon a carbon adsorption rate of 0.65 lb TNT/lb carbon. The PVUC costs for the UV-Ozone treatment alternative decrease linearly (from \$9.40/K-GAL for the 10^5 GPD and \$8.00/K-GAL for the 10^6 GPD flow) with decreasing numbers of UV lamps. However, even at the lowest value of 2 lamps per square foot of reactor surface

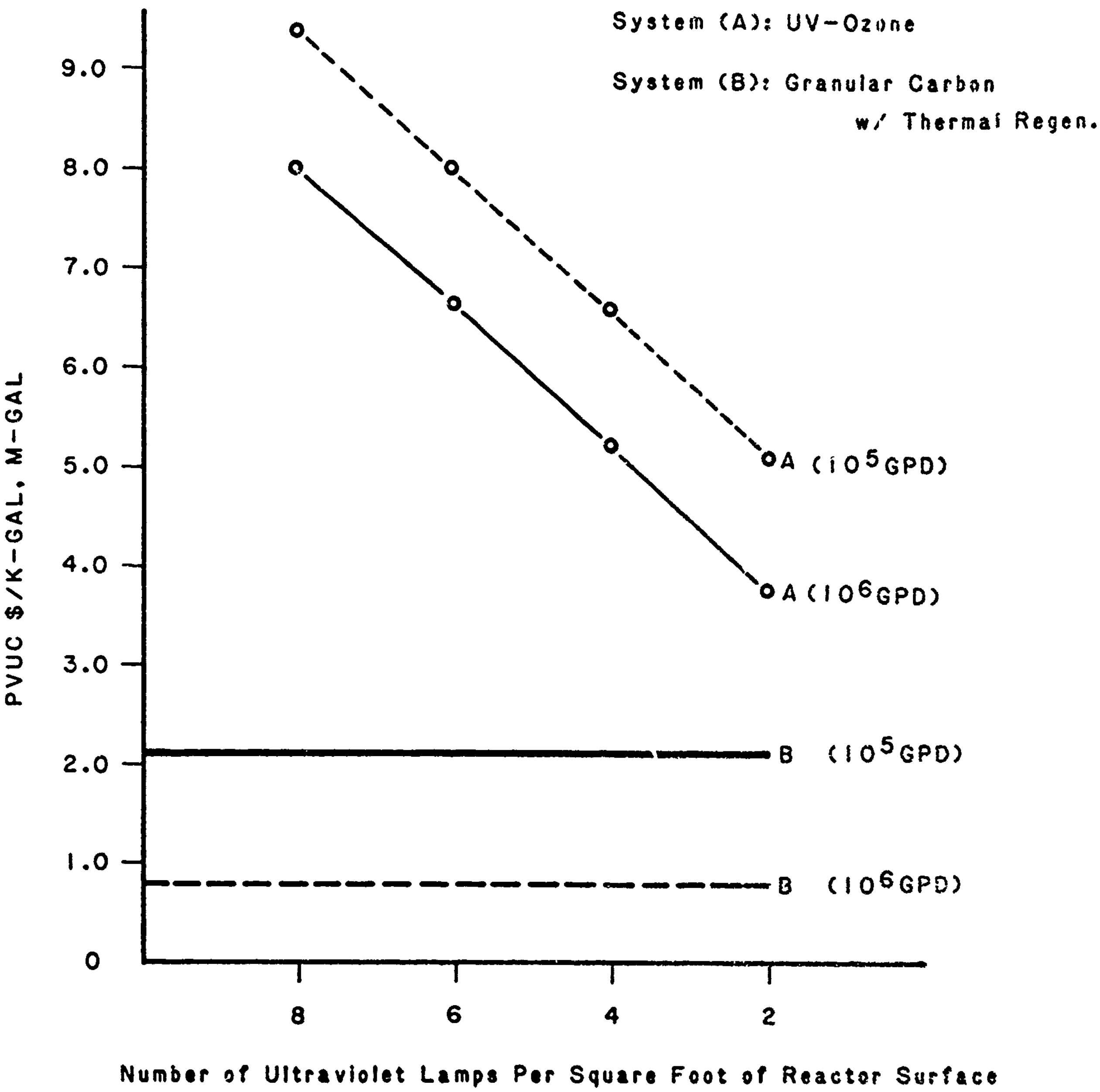


FIGURE 3.2.2
SENSITIVITY OF THE UV-OZONE ALTERNATIVE TO THE NUMBER OF UV LAMPS USED

area the calculated PVUC costs are substantially higher, i.e., \$5.20/K-GAL for the 10^5 GPD and \$3.80/K-GAL for the 10^6 GPD, than the baseline costs of \$2.20 and \$0.82/K-GAL respectively for the granular carbon with thermal regeneration alternative.

One must note here that the question of pink water removal efficiencies has not yet been assessed as the number of UV lamps was decreased. It is anticipated that efficiencies would decrease sharply even though they were held constant in this set of calculations. In spite of holding efficiencies constant, the calculated PVUC, even at the 2 UV lamps per square foot value, was still higher than the granular carbon alternative.

3.2.3 Sensitivity of the Surfactant Complexing Alternative to Varying Surfactant Dosages Compared with Granular Carbon with Thermal Regeneration.

In the treatment of the pink waters by the Surfactant Complexing alternative, the dosage of Duoquad* surfactant required (127 lbs/day) and its cost (\$1.00/lb) are two very significant variables affecting the economic competitiveness of this technology. This sensitivity analysis considered the impact of these factors on the calculated PVUC when this technology was compared with thermally regenerated carbon at a flow rate of 10^5 GPD.

The information presented in Figure 3.2.3 is based on the granular carbon having an adsorption rate of 0.65 lbs TNT/lb carbon. The point, where both alternatives would be economically equivalent, is calculated to be at about a surfactant dosage of 85 lbs/day. That is, if the Surfactant Complexing alternative is to be considered as strong competition for the Granular Carbon With Thermal Regeneration, then the maximum dosage for Duoquad at a unit price of \$1.00/lb must be about 85 lbs/day. To be more favorable, the Duoquad dosage must be less than 85 lbs/day and achieve the same pink water removal efficiency. Use of a less efficient carbon, say 0.2 lbs TNT/lb carbon (at 10^5 GPD), raises the Granular Carbon with Thermal Regeneration alternative PVUC to approximately \$2.50/K-GAL, slightly increasing the range over which Surfactant Complexing alternative would be cost competitive. On the other hand, the use of more efficient carbon (i.e., 1.0 lb TNT/lb carbon) would reduce the Granular Carbon

*Duoquad T-50 has exhibited mutagenic characteristics.[37]

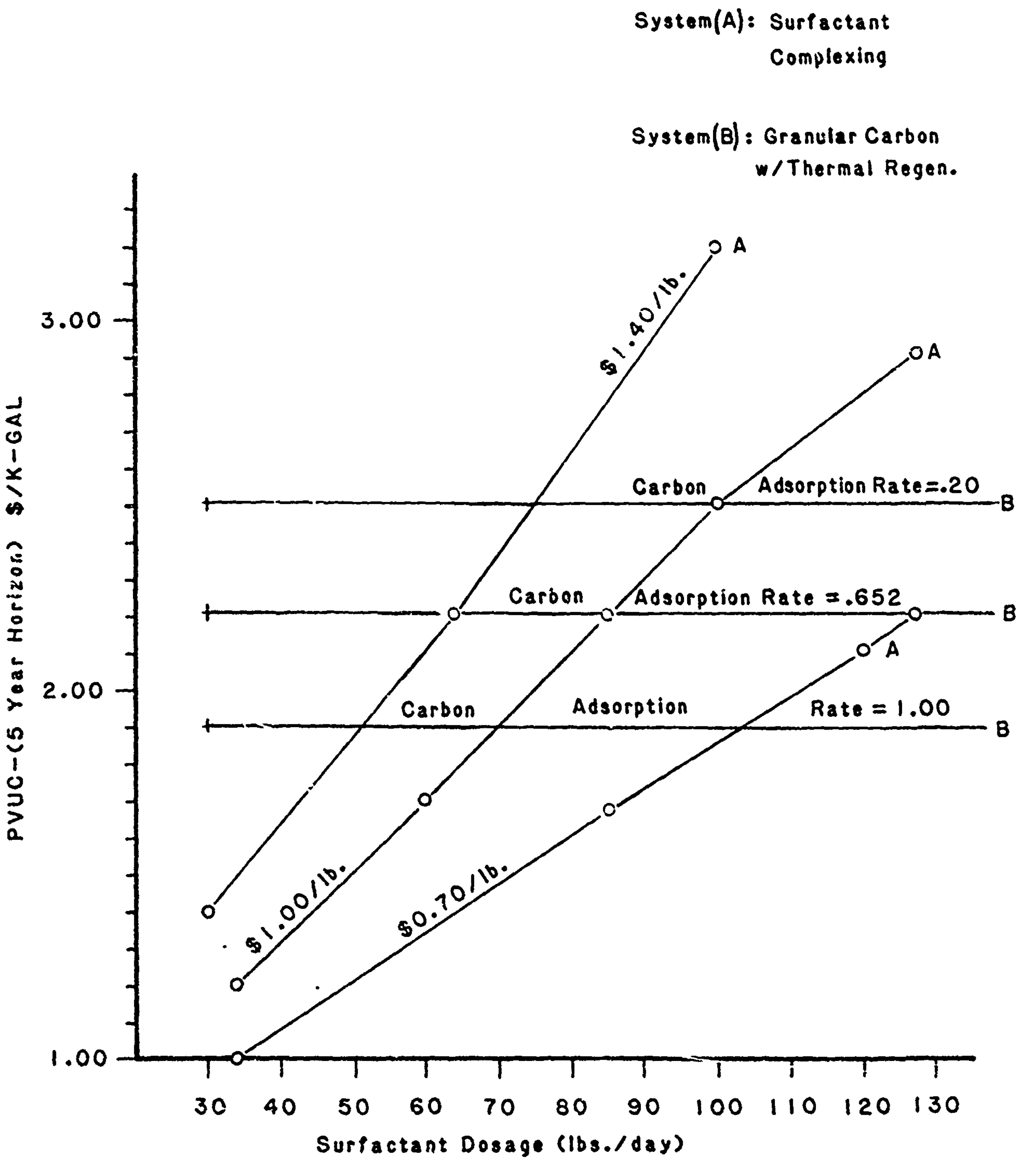


FIGURE 3.2.3

SENSITIVITY OF THE SURFACTANT COMPLEXING ALTERNATIVE TO THE REQUIRED DOSAGE & PRICE

100,000 GPD

with Thermal Regeneration alternative baseline PVUC to about $1.90/KGAL thereby decreasing the economic competitiveness of the Surfactant Complexing alternative.

As surfactant costs vary, the amount of surfactant that can be used and still keep that alternative competitive with thermally regenerated carbon decreases from a high dosage of approximately 128 lbs/day at $0.70/lb to about 75 lbs/day surfactant dosage costing $1.40/lb. Thus, as the price of surfactant increases to $1.40/lb, the surfactant dosage required to make that alternative equivalent to the carbon would have to approach approximately 65 lbs/day.

Two factors which have been minimized in the analyses of the surfactant complexing alternative are:

a) the assumption that the rotary vacuum filtration of the complexed and settled pink waters is feasible; and
b) the ultimate disposal of the concentrated sludge generated in this treatment.

The first factor has the effect of greatly reducing the size of the vacuum filtration equipment required while the second presumes that ultimate disposal is available within the confines of the installation but not constructed and operated as a dedicated process to the Surfactant Complexing alternative treatment system. Hence, one must anticipate that although Surfactant Complexing appears to be a competitive alternative to the Granular Carbon With Thermal Regeneration alternative, these two factors would interplay to increase the unit cost of the surfactant treatment.

Another consideration worthy of further discussion is the relative strengths of the respective data bases for these two alternatives. The data sets for Granular Carbon With Thermal Regeneration are extensive with operating experiences documented at both the laboratory- and pilot-scale. While the Surfactant Complexing alternative has been conducted only on the smaller research bench-scale, and hence the data sets for both surfactant removal efficiencies and costs are not as extensive nor complete as for granular carbon.

The data presented in Figure 3.2.3 indicate quantified direction objectives and goals that must be achieved in order to make the Surfactant Complexing

alternative a serious contender to thermally regenerated granular carbon.

3.2.4 Sensitivity of the Powdered Carbon Alternative to the Adsorption Rate of the Powdered Carbon and to the AST Regeneration Costs.

As with granular carbon, the adsorption rate for powdered carbons was analyzed for impact upon their calculated PVUC's. Here the unit process of interest was the clarifier and the associated dosages of powdered carbon needed to effectively remove the dissolved TNT. Figure 3.2.4 shows the results obtained by varying the adsorption rate, for both the 10^5 and 10^6 GPD flow rates. As might be expected, an increase in carbon efficiency would decrease the unit cost of treatment. Specifically, there were decreases of 55 percent and 64 percent respectively for 10^5 GPD and 10^6 GPD flows as carbon efficiency increases from 0.2 to 1.0 lbs TNT/lb powdered carbon. An examination of Figure 3.2.4 suggests that the comparative competitiveness of the two systems at either of the flow rates studied, will not be altered by merely increasing the efficiency of the powdered carbon.

Figure 3.2.5 presents the results obtained when both the capital and operating costs of the AST regeneration process were reduced by increments of 25 percent from the base furnace cost of $134,000 to 25 percent of that value, in order to estimate its effect upon the powdered carbon alternative. Successive cost reductions were compared with the Granular Carbon With Thermal Regeneration alternative in an attempt to determine if there existed a cost equivalency point. A cross-over point was not obtained (Figure 3.2.5) indicating that even if reductions to 25 percent of furnace capital costs in the AST regeneration process could be achieved, the PVUC of the Powdered Carbon alternative would still remain higher than that for the Granular Carbon alternative.

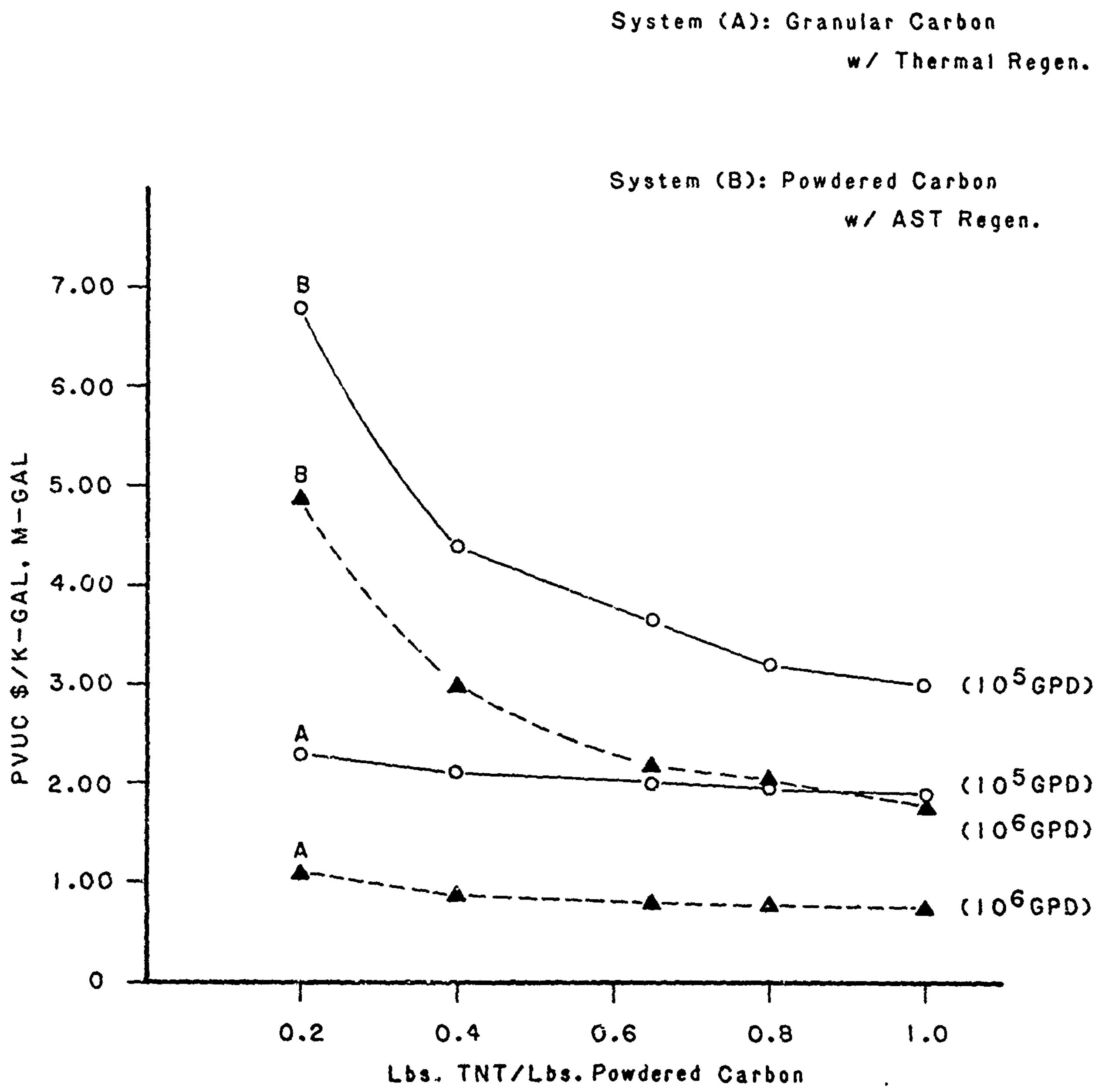


FIGURE 3.2.4
SENSITIVITY OF THE POWDERED CARBON ALTERNATIVE TO
THE ADSORPTION RATE OF THE CARBON

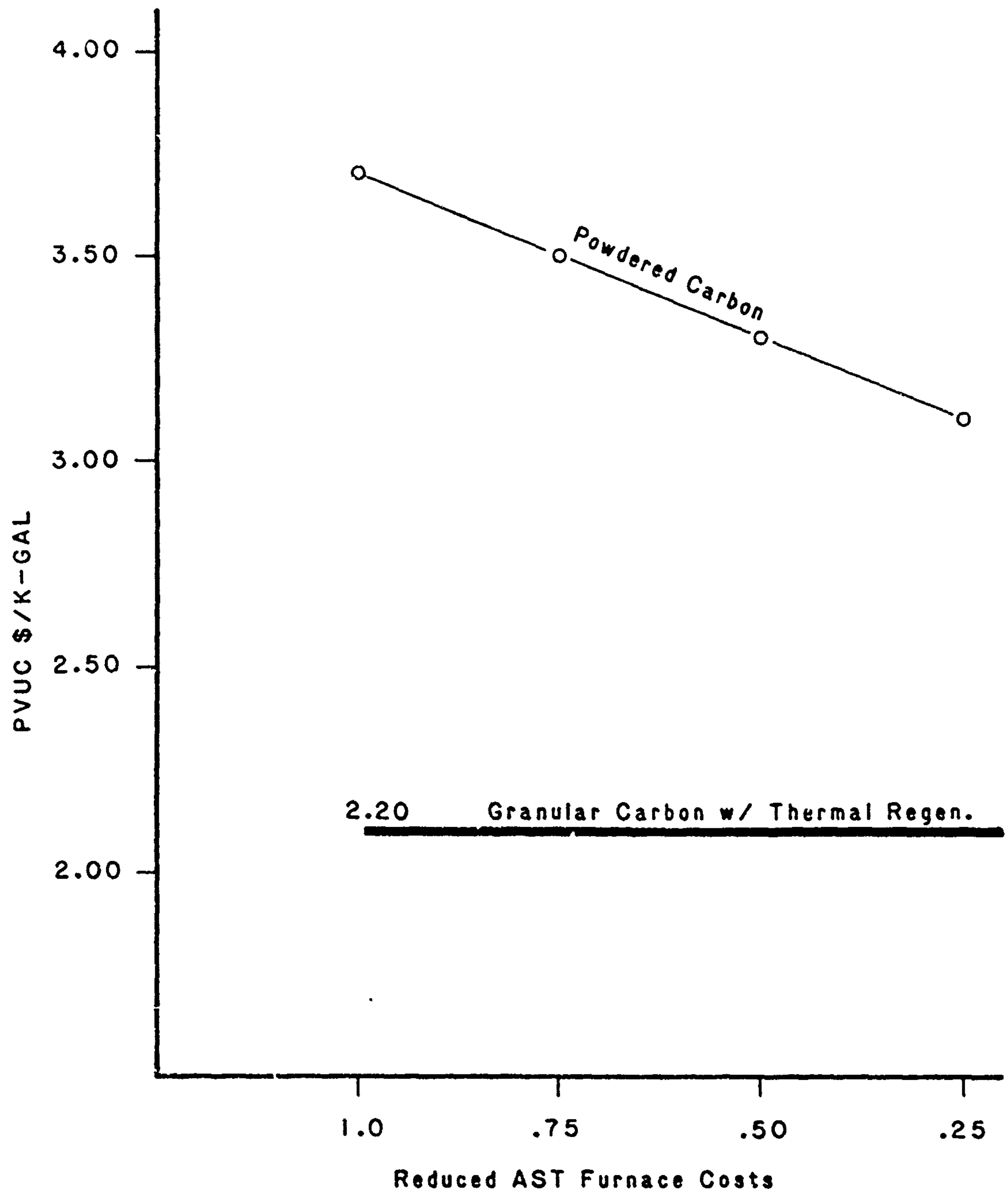


FIGURE 3.2.5

SENSITIVITY OF THE POWDERED CARBON ALTERNATIVE TO REDUCED AST CARBON REGENERATION COSTS

100,000 GPD

4.0 CONCLUSIONS (NOT IN ANY ORDER OF PRIORITY)

1. Based on the PVUC cost analyses of the seven feasible pink water treatment alternatives:
   a) The most promising state-of-the-art methods in a low-to-high order of increasing unit treatment costs are:
      i) Granular carbon with regeneration
      ii) Granular carbon without regeneration
      iii) Surfactant complexing
      iv) Powdered carbon
      v) UV-Ozone

   b) The least promising state-of-the-art methods in a high-to-low order of decreasing unit treatment costs are:
      i) Ultrafiltration
      ii) Liquid/liquid extraction

2. Based on the extensive literature search and review conducted:
   a) The best documented pink water treatment processes are the granular carbon methods.
   b) The least documented pink water treatment processes are the surfactant complexing, ultrafiltration and liquid/liquid extraction methods.

3. The non-regenerative granular carbon alternative is particularly sensitive to the TNT/carbon adsorption rate but only appears to be so to an adsorption rate of 0.6 and not beyond.

4. In the thermal regenerative granular carbon alternative, the calculated PVUC costs for the lowest carbon adsorption rate (0.2) is not significantly greater than the PVUC costs for the more efficient exchange rate (0.65).

5. The surfactant complexing alternative, when compared to the regenerative carbon system, becomes less cost attractive as the TNT/carbon adsorption rate increases from 0.2 to 0.65 and beyond to 1.0 (two other factors minimized; see Section 3.2.3).

6. The cost competitiveness of the regenerative powdered carbon system as compared with the regenerative granular carbon system is not altered by increasing the adsorption efficiency of the powdered carbon.

7. The competitiveness of the powdered carbon system as compared with the regenerative granular carbon system is not altered even if the AST furnace cost is reduced 75 percent.

5.0 RECOMMENDATIONS

In order to economically treat pink water to meet expected discharge limits, it is recommended that the U.S. Army:

5.1 Conduct research efforts to improve the efficiencies of those unit processes identified in the Granular Carbon With Thermal Regeneration alternative. Efforts should be directed towards more effective regeneration processes rather than improving the carbon adsorption rates.

5.2 Continue research on the Surfactant Complexing alternative to determine efficient clarifying techniques and to identify a more efficient complexing agent free of either mutagenic or carcinogenic characteristics.

5.3 Conduct research to document the performance characteristics of surfactant complexing clarification, sludge dewatering and ultimate disposal.

5.4 Consider the applicability of combined treatment methods to the processing of pink wastewaters. (Based on the literature review, indications are that combined systems present a viable alternative worthy of further consideration).

6.0 REFERENCES

1. Catherine C. Andrews, Photooxidative Treatment of TNT Contaminated Waste Water, Weapons Quality Engineering Center, Naval Weapons Support Center, Crane, IN, WQEC/C 80-137, Jan. 1980.

2. Army Environmental Hygiene Agency, Carbon Column System Removal Efficiency Study, Iowa Army Ammunition Plant, USAEHA, Aberdeen Proving Ground, MD, Study No. 24-033-73/74, Feb. 1974.

3. Robert I. Brabets and Gayle E. Marks, Ozonolysis of Pink Water, Phase I, IIT Research Institute, Chicago, IL, IITRI-C6275, 1974.

4. John A. Brown and Bossie Jackson, Jr., White Oil Solvent Extraction of TNT from Pink Wastewater, Large Caliber Weapons System Laboratory, USAARADCOM, Dover, NJ, ARLCD-TR-79020, Dec. 1979.

5. Stephen L. Brown, Joel M. Cohen, Nigel I. Marcrea, and Mitchell J. Small, Setting Priorities for R&D on Army Chemicals, Contract DAMD 17-75-C-5071, SRI International, Menlo Park, CA, CRESS Report No. 56, May 1978.

6. William Buckley, Jr., Bossie Jackson, Jr., and Milton Roth, "Advanced Technology for Abatement of Nitrobody Pollution," Safety, Pollution Abatement, and Conservation of Energy Review (SPACER) for Munitions Plant Modernization Third Presentation for the Army Research Office (ARO), Large Caliber Weapon Systems Laboratory, ARRADCOM, Dover, NJ, Sept. 1979.

7. V. J. Ciccone, et al., "A Present Value-Unit Cost Methodology for Evaluating Wastewater Reclamation and Direct Reuse," Water Resources Bulletin, Vol. 11, No. 1, 1975.

8. David G. Derrick and Jerry R. Perrich, "Guide to Ozone Equipment Selection," Pollution Engineering, 42-44, Nov. 1979.

9. Environmental Protection Agency, Solvent Extraction Status Report, Environmental Protection Technology Series, EPA-R2-72-073, Dec. 1972.

10. Frank C. Farrell, Jack D. Zeff, Thomas C. Crase, David T. Boylan, Development Effort to Design and Describe Pink Water Abatement Processes, Final Technical Report, Westgate Research Corporation, West Los Angeles, CA, Aug. 1977.

11. Iowa Army Ammunition Plant, "Nitrobody Characterization of Pink Wastewater at Iowa AAP (Preliminary)", undated.

12. Iowa Army Ammunition Plant, "UV/Ozonolysis Treatment of Pink Wastewater/Iowa AAP, 100,000 Gallons/Day - One Load Line (Full Mobilization) (Preliminary)", undated.

13. Bossie Jackson, Jr., "Pink Water Treatment and Disposal", Safety Pollution Abatement, and Conservation of Energy Review (SPACER) for Munitions Plant Modernization Second Presentation for the Army Research Office (ARO), Large Caliber Weapon Systems Laboratory, ARRADCOM, Dover, NJ, May 1978.

14. J. M. Morgan, Jr., V. J. Ciccone and J. E. Martin, Economic Evaluation of Munitions Manufacturing Wastewater Treatment Alternatives Using a Present Value-Unit Cost Methodology, Prepared for U.S. Army Mobility Equipment and Development Command, Ft. Belvoir, VA, Contract No. DAAK70-76-C-0052, Feb. 1980.

15. "Nitrobody Characterization of Pink Wastewater at Iowa AAP", (Preliminary), Feb. 18, 1981, (Anon).

16. Notes, working meeting, MERADCOM, Ft. Belvoir, VA, 3 July 1980.

17. Notes, working meeting, USATHAMA, Aberdeen Proving Ground, MD, 31 July 1980.

18. Notes, working meeting, USAARADCOM, Dover, NJ, 22 Oct. 1980.

19. Notes, working meeting, IAAP, Burlington, IA, 10-11 Dec. 1980.

20. Notes, working meeting, USAARADCOM, Dover, NJ, 12 Jan. 1981.

21. Notes, working meeting, NATICK, Natick, MA, 9 Feb. 1981.

22. Notes, working meeting, VJCA, Woodbridge, VA, 12 Feb. 1981.

23. Notes, working meeting, VJCA, Woodbridge, VA, 29 May 1981.

24. Notes, working meeting, USATHAMA, Aberdeen Proving Ground, MD, 16 July 1981.

25. James Patterson, John Brown, William Duckert, Jack Polson, and Norman I. Shapira, State-of-the-Art-Study: Wastewater Treatment in the Military Explosives and Propellants Production Industry, Vol. I, Technical Report, American Defense Preparedness Assoc., Washington, DC, Oct. 1975.

26. James Patterson, John Brown, William Duckert, Jack Polson, and Norman I. Shapira, State-of-the-Art-Study, Wastewater Characteristics, Vol. II, American Defense Preparedness Assoc., Washington, DC, Oct. 1975

27. James Patterson, John Brown, William Duckert, Jack Polson, and Norman I. Shapira, State-of-the-Art-Study: Wastewater Treatment, Vol. III, American Defense Preparedness Assoc., Washington, DC, Oct. 1975.

28. Y. Okamoto, E. J. Chou, M. Crole, and M. Roth, Application of Foam Separation to Aqueous Solutions of Trinitrotoluene (TNT) Part II, Removal of Organic Explosives with Surfactants, Large Caliber Weapon Systems Laboratory, USAARADCOM, Dover, NJ, ARLCD-CR-78020, Dec. 1978.

29. Y. Okamoto, E. J. Chou, and J. Yang, The Removal of 2, 4, 6-Trinitrotoluene (TNT) from Aqueous Solution with Surfactants, Large Caliber Weapons System Laboratory, USAARADCOM, Dover, NJ, ARLCD-TR-77038, Oct. 1977.

30. Jerry L. Osmon and C. C. Andrews, The Biodegradation of TNT in Enhanced Soil and Compost Systems, Large Caliber Weapon Systems Laboratory, USAARADCOM, Dover, NJ, ARLCD-TR-77032, Jan. 1978.

31. Milton Roth and Egerton A. Boyce, Continuous Monitoring of Pink Water from Carbon Adsorption Process, Large Caliber Weapon System Laboratory, USAARADCOM, Dover, NJ, ARLCD-TR-77047, Apr. 1978.

32. Milton Roth and Joseph M. Murphy, Jr., Ultraviolet-Ozone and Ultraviolet-Oxidant Treatment of Pink Water, Large Caliber Weapon Systems Laboratory, USAARADCOM, Dover, NJ, Nov. 1978.

33. T. R. Sundaram, J. E. Santo, and A. F. Tatyrek, Hydroperm Microfiltration System for Treatment of TNT Pink Wastewater - Part I, No Pretreatment, Large Caliber Weapon Systems Laboratory, USAARADCOM, Dover, NJ, ARLCD-CR-80031, Apr. 1981.

34. James M. Szachta, Analysis of Carbon versus Resin, Chemical Systems Laboratory, USAARADCOM, Aberdeen Proving Ground, MD, ARLSL-TR-78013, March 1978.

35. James E. Tash, William S. Layne, and Phillip A. Goodfellow, Liquid-Liquid Extraction of TNT from Pink Water with Paraffinic (White) Oil or Toluene, Technical Report No. 327, Mason & Hanger - Silas Mason Co., Inc., Iowa Army Ammunition Plant, 30 Dec. 1980.

36. Alfred F. Tatyrek, Treatment of TNT Munitions Wastewaters - The Current State of the Art, Technical Report 4909, Picatinny Arsenal, NJ, Oct. 1976.

37. Committee on Environmental Sciences and Resources Recovery of the Advisory Board on Military Personnel Supplies, ABMPS Report No. 115, Periodic Report, National Research Council, National Academy Press, Washington, DC, 1981.

38. Federal Register, Environmental Protection Agency, Hazardous Waste Management System, Vol. 45, No. 98, May 19, 1980.

39. Federal Register, Environmental Protection Agency, Hazardous Waste Management System: Identification and Listing of Hazardous Waste, Vol. 46, No. 221, November 17, 1981.

7.0 GLOSSARY OF SELECTED TERMS

Atomized Suspension Technique (AST):

A thermal method for regenerating powdered carbon.

DNT (Dinitrotoluene):

A nitrobody, which has been identified as a potential carcinogen.

Granular Carbon Adsorption:

A method of attracting and accumulating certain organic materials, including TNT, on the surface of activated granular carbon. The granular carbon may or may not be thermally regenerated for cost incentive. Regenerated carbon may be reused; non-regenerated carbon is used on a once-through basis.

HMX (Cyclotetramethylene-tetranitramine):

A nitrobody found in pink water.

Laboratory-Scale Experiments:

Bench-type research confined generally to chemistry laboratory experimentation involving glass or plastic hardware and flexible tubing usually of a temporary nature.

Liquid/Liquid Extraction:

A counter current flow of TNT wastewaters versus an immiscible solute which distributes by stages between the two liquids to reach an equilibrium and extraction of the TNT.

Load, Assemble and Pack (LAP):

Mechanical operations located at Army Ammunition Plants involving loading, unloading, assembling and demilitarizing various shell casings and munitions canisters.

Nitrobodies:

Nitro compounds which includes DNT, HMX, RDX and various isomers of TNT which may be toxic and hazardous. Nitrobodies may include sellite process products and by-products from the munitions production process.

Pilot-Plant Scale Experiments:

Half-size or less research experimentation confined generally to chemical engineering type laboratory experimentation involving manufactured or designed hardware of a semi-permanent nature.

Pink Water or Pink Wastewater:

A common name given to the complex aqueous colored waste at all TNT manufacturing plants, at all LAP operations where propellants and explosives containing TNT are transformed into live munitions, or where TNT-loaded munitions are demilitarized or unloaded. Pink waters, so-called because of their characteristic color, contain mostly TNT and lesser amounts of other nitro compounds (nitrobodies).

Powdered Carbon Adsorption:

A TNT treatment method in which the unwanted constituents are adsorbed on well-mixed, finely divided activated carbon particles which may be thickend into a sludge. The resulting carbon sludge may be reprocessed by an Atomized Suspension Technique for carbon reuse.

Present Value-Unit Cost:

A methodology utilizing a computerized mathematical model approach which considers capital and operating costs, depreciation, interest, effects of inflation, salvage value, and other related factors over varying periods of time (see Time Horizons) and wastewater loading rates. The relative cost of each alternative yields the minimum cost per thousand gallons of wastewater to be treated daily over the anticipated time horizons.

RDX (Cyclotrimethylene-trinitramine):

A nitrobody found in pink water.

Red Water:

A highly concentrated sulfonated nitrobody generated in the TNT purification process which utilizes sellite, a solution (16 percent) of sodium sulfite; the sellite solution and the accompanying rinse waters constitute the red water.

Surfactant Complexing:

A method of reducing TNT concentrations in pink water by the addition of a surfactant in the presence of a strong alkaline and later neutralizing the waste with an acid. Sludges are expected to result from the process.

Time Horizon:

Six periods of five years each which serve as computation parameters for PVUC over the thirty year lifespan of the treatment system.

TNT (2,4,6-trinitrotoluene):

Exists as 2,4,6-trinitrotoluene (alpha-TNT) $[(NO_2)_3C_6H_2CH_3]$, an aromatic ring compound.

Ultrafiltration:

The process of removing TNT material by a pressure active physical separation process employing a selective porous membrane to restrict the passage of unwanted material.

Ultraviolet-Ozone:

The process of treating TNT wastes by two processes simultaneously. Ozone is induced into the pink waters and the waters are permitted to flow around banks of ultraviolet light lamps.

USARRADCOM:

U.S. Army Armament Research and Development Command, Dover, New Jersey.

USATHAMA:

U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland.

USAMERADCOM:

U.S. Army Mobility Equipment Research and Development Command, Ft. Belvoir, Virginia.

$/K-GAL:

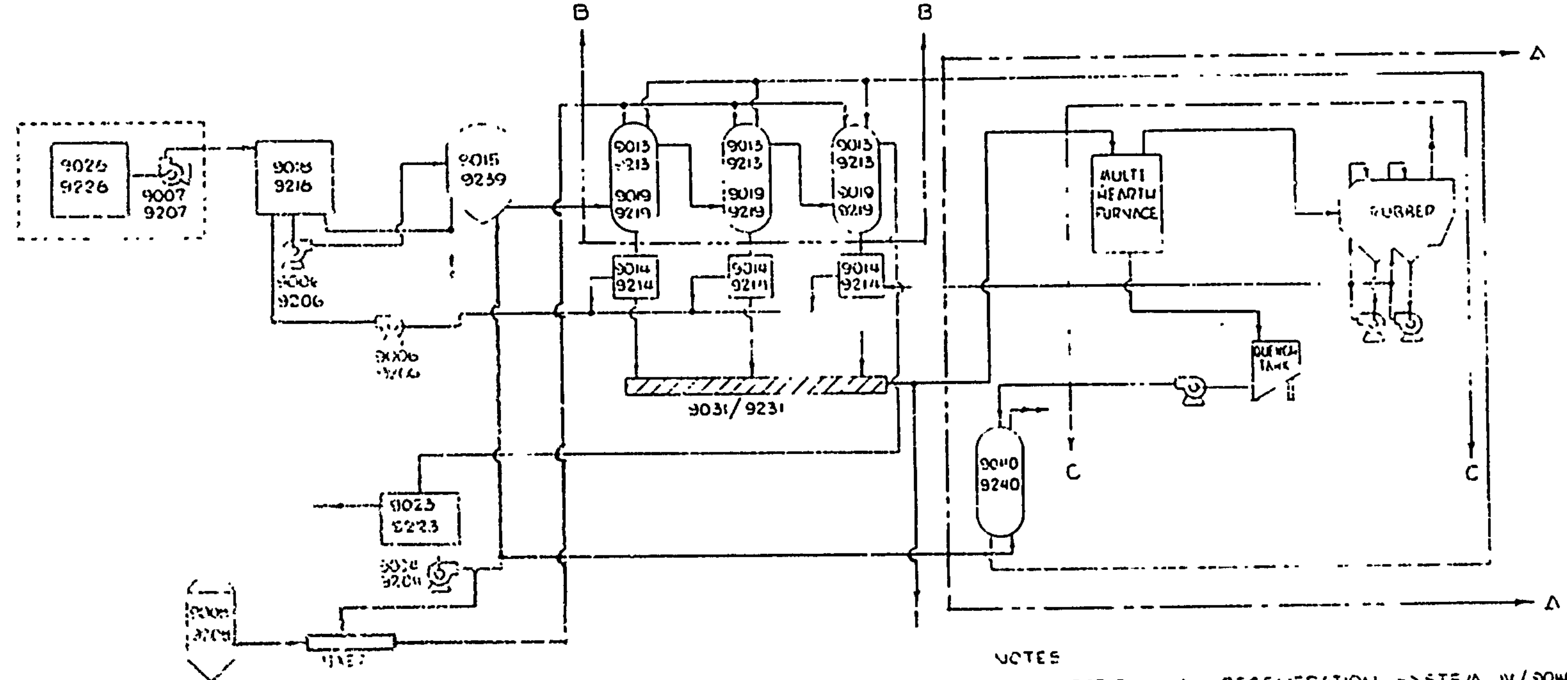
Dollars per thousand gallons.

$/M-GAL:

Dollars per million gallons.

APPENDIX A

FLOW DIAGRAMS AND DESIGN DATA SHEETS



PVUC CAT NUMBER 105GPD	10+GPD	NOMENCLATURE
9004	9204	PUMP-BACKWASH FILTER
9006	9206	PUMP-PRESSURE EQUALIZATION
9007	9207	PUMP-PRESSURE SUMP
9008	9208	VIRGIN CARBON STORAGE TNK
9011	9211	CARBON REGENERATION SYSTEM
9013	9213	CARBON COLUMN - GRANULAR (W/O REGEN)
9014	9214	WASTE CARBON TANK
9015	9239	FILTER PRESSURE-DE (OR MIX MEDIA)
9018	9216	EQUALIZATION SEDIMENTATION TNK
9019	9219	CARBON COL WITH THERMAL REGEN
9023	9223	HOLDING TANK
9026	9226	SUMP
9031	9231	CONVEYOR, SCREW
9040	9240	CARBON DE-FINE TANK

NOTES

1 - SECTION A-A = REGENERATION SYSTEM W/9040/9240

2 - SECTION B-B = 9013 9213 W/O REGENERATION

3 - SECTION C-C = REGENERATION SYSTEM 9011/9211

FIGURE A-1, GRANULAR CARBON ADSORPTION

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70-80-C-0101

THIS DOCUMENT IS PROPRIETARY TO V.J. CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±

DRAWN SS 3 5 81

CHECKED

APPROVED

DATE

V. J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

GRANULAR CARBON ADSORPTION

SIZE C FSCM

DWG NO. FIGURE A-1

SCALE

SHEET 1 OF 15

TABLE A-1a. DATA SHEET, GRANULAR CARBON ADSORPTION 10^5 GPD

PVUC CAT NUMBER	9004	9006	9007	9008	9011	9013	9014	9015	9016	9019	9023	9028	9031	9040
NOMENCLATURE	PUMP BKWH	PUMP PRESS.	PUMP SUMP	TANK V.CARBON	REGEN. SYSTEM	CARBON COLUMN	WASTE TANK	FILTER D.E.	TANK EQUAL	CARBON COLUMN	TANK HOLDING	SUMP	CONVR. SCREW	TANK DE FINE
DIMENSIONS	2×2	2×2	2×2	8'0"×40'H	6'0"D	7'0"D·16'0"H	15'0"·8'0"H	2'5"×5'0"H	40'×15'×6'	7'0"×16'0"H	19'0"×12'0"H	8'0"×12'0"H	9'0"×25'0"L	7'0"×16'0"H
CAPACITY				20,000 (40,000 GAL)	6720 LBS/DY	566 CU FT CARBON	10,000 (12,000 GAL)		100,000 GAL	300 CU FT	25,000 GAL	20,000 GAL		5070 (2500)
MATERIAL	M.I	M.I	M.I	STEEL	M.I	STEEL	STEEL	COATED M.I	STEEL	STEEL	STEEL	STEEL	STEEL	STEEL
TYPE	CNTFGL	CNTFGL.	CNTFGL.	VERT CYL.	5-HEARTHS	GRANULAR	VERT CYL	VERT CYL	RECT.	GRANULAR	VERT CYL	VERT CYL	CYL	VERT CYL
ENERGY REQ.	2.5 Kwh	4 Kwh	4 Kwh										15 Kwh	4 Kwh
PRESSURE	45 PSI	65 PSI	25 PSI			25 PSI		45-55 PSI		25 PSI				
RATE	70 GPM	70 GPM	150 GPM		4 LBS/FT²	70 GPM		70 GPM		70 GPM			250 LBS/HR.	BKWH WATER 200 GPM
HYDR LOAD					280 LBS/HR	1.8 GPM/FT²		2.5 GPM/FT²		1.8 GPM/FT²				
EFFECTIVE AREA					HEARTH AREA 70 FT²	38.5 FT²		28 FT²		38.5 FT²				
MEDIA VOLUME						3665 LBS/COLUMN		22 LBS/DY		3665 LBS/COLUMN				
BKW PERIOD								5 MIN						
BKW RATE								70 GPM						
HYDRAULIC HP	1.9 HP	2.6 HP (2.64)	2.2 HP (7.58)											
DETN TIME					30 MIN	35 MIN			24 HRS	35 MIN		~7 HRS		15 MIN
EQUIP QUANTITY	1	2	2	1	1	1 UNIT + 3 COLUMNS	3	2	1	1		1	1	1
OTHER DATA				3-CARBON COLUMN		WITHOUT REGEN	1/CARBON COLUMN			W/ REGEN ONLY				

NOTE.
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100
CONTRACT DAAK 70-80-C-0101
THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±
DRAWN SJ 3581
CHECKED
APPROVED
DATE

V. J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES
GRANULAR CARBON ADSORPTION 10^5 GPD
SIZE C | FSCM | DWG NO TABLE A-1a
SCALE | SHEET 2 OF 18

TABLE A-16, DATA SHEET. GRANULAR CARBON ADSORPTION 10^6 GPD

PVUC CAT NUMBER	9204	9206	9207	9208	9211	9213	9214	9216	9219	[illegible]	9226	9231	9239	9240
NOMENCLATURE	PUMP BKWH	PUMP PRESS.	PUMP SUMP	TANK V CARBON	REGEN SYSTEM	CARBON COLUMN	WASTE TANK	TANK EQUAL	CARBON COLUMN	TANK HOLDING	SUMP	CONVR SCREW	FILTER # 3	TANK OF-FINE
DIMENSIONS	4x5	3x4	3x4	170D 120H	6 G'DIA	12 DO.27OH	120D.120H	120-75 12	120 D.27OH	[illegible]	[illegible]	[illegible]	250.DC [illegible]	[illegible]
CAPACITY				25000 GAL (24000)	[illegible]/DY	2812 CU FT (CARBON)	25,000 GAL	250 000 GAL	2812 CU FT (CARBON)	25 000 GAL	200 000 GAL			25000 GAL
MATERIAL	M I	M I	M I	STEEL		COATED STEEL	COATED STEEL	CONCRETE	COATED STEEL	STEEL	STEEL	STEEL	COATED M I	STEEL
TYPE	CNTFGL	CNTFGL.	CNTFGL	VERT. CYL	6 HEARTHS	VERT CYL.	VERT CYL	RECT	VERT CYL	VERT CYL	VERT CYL		VERT CYL	VERT CYL
ENERGY REQ.	25Kwh	25Kwh	25Kwh											
PRESSURE	25PSI	45 PSI	45 PSI											
RATE	1200GPM	700GPM	700GPM		4LB / FT2	700 GPM		350 GPM	700 GPM				350 GPM	
HYDR LOAD					[illegible] / HR	6.14 GPM PER FT2			6.14 GPM PER FT2				[illegible]	
EFFECTIVE AREA					5C FT2/ HEARTH	1150.4 FT2			120.4 FT2				117 FT2	
MEDIA VOLUME						90,000 LBS/ COLUMN			90,000 LBS/ COLUMN				350 [illegible]	
BKW PERIOD	10 MIN												[illegible] MIN	
BKW RATE	15GPM/FT2												[illegible]/FT2	
HYDRAULIC HP	18 HP (31.6)	18.3 HP (26.6)	18.3 HP (7.6)											
DETN TIME						30 MIN		12 HRS						
EQUIP. QUANTITY	1	2	2	1	1	1 UNIT-3 COLUMNS	3	2	1	1	2	3	4	1
OTHER DATA				1-CARBON COLUMN		WITHOUT REGEN.			W/ REGEN ONLY					

NOTE
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

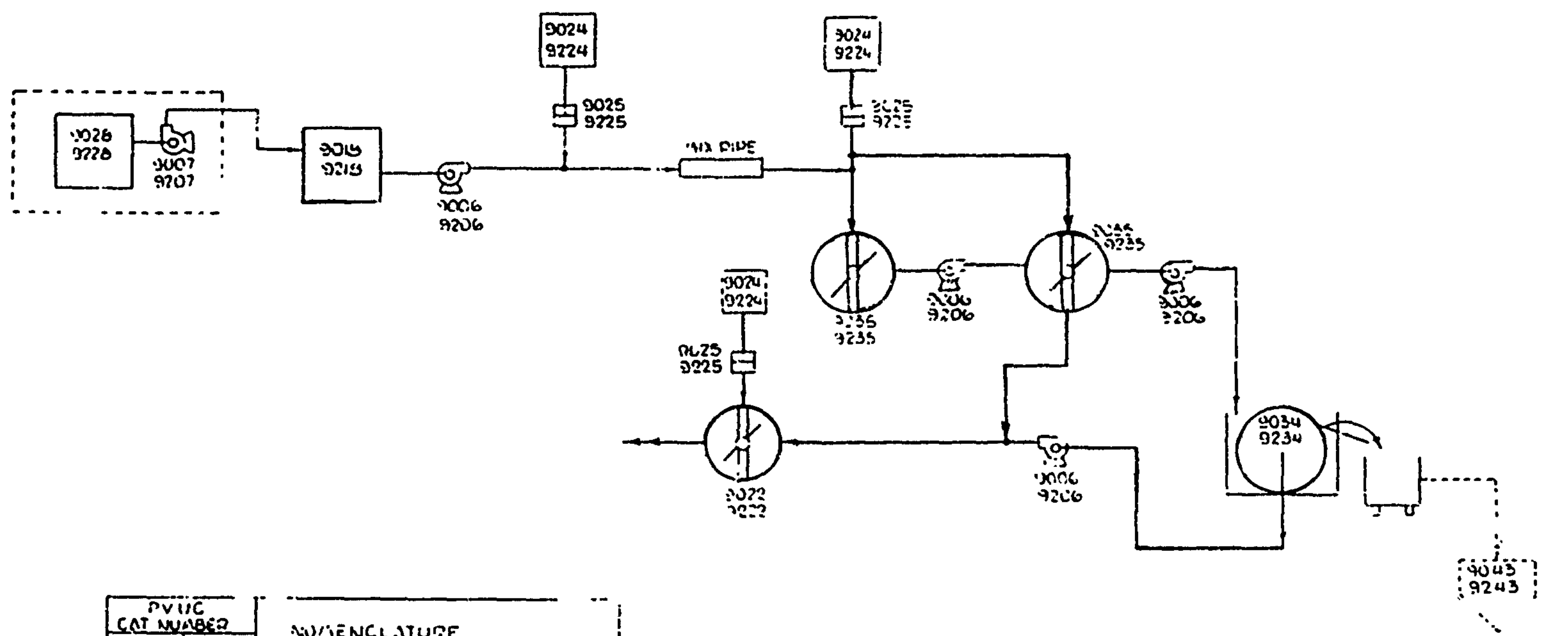
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100
CONTRACT DJAK 70 80 C 0101
THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES: 3 PLACE DECIMALS: 2 PLACE DECIMALS:
DRAWN SJ 9-81
CHECKED
APPROVED
DATE

V. J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

GRANULAR CARBON ADSORPTION 10^6 G.P.D

SIZE C FSCM DWG NO TABLE A-16
SCALE SHEET 3 OF 18



PVMC CAT NUMBER 10^5GPD	10^6GPD	NOMENCLATURE
9006	9206	PUMP- PRESSURE EQUALIZATION
9007	9207	PUMP- PRESSURE SUMP
9018	9218	EQUALIZATION SEDIMENTATION TNK.
9022	9222	NEUTRALIZATION TANK
9024	9224	SURFACTANT MIX TANK
9025	9225	CHEMICAL FEEDER
9028	9228	SUMP
9034	9234	VACUUM FILTER PWD CARBON
9035	9235	SURFACT REACT TANK
9043	9243	INCINERATOR

FIGURE A-2. SURFACTANT COMPLEXING

CONTRACT DAAK 70-80-C-0101

V J CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

SURFACTANT COMPLEXING

SIZE C — DWG NO. FIGURE A-2 — SHEET 4 OF 18

TABLE A-2a. DATA SHEET, SURFACTANT COMPLEXING 10^5 GPD

PVUC CAT NUMBER	9006	9007	9016	9022	9024	9025	9029	9034	9035	9043
NOMENCLATURE	PUMP PRESS	PUMP SUMP	TANK EQUAL	NEUT. TANK	SURF. MIX TANK	FEEDER CHEMICAL	SUMP	VACUUM FILTER	TANK SURFACT	INCIN.
DIMENSIONS	2×2	2×2	90'×45'×8'	8.0'D×14.0'H	3.0'×3.0'×6.0'		18.0'D×20'H	2.5'D×2.5'W	8.0'D×14.0'H	
CAPACITY			100,000	5,000 GAL	500 GAL		20,000 GAL	360 LBS/DY DRY SOLID	5275 GAL	
MATERIAL	A.I.	A.I.	STEEL	COATED STEEL	COATED STEEL		STEEL	A.I.	STEEL	
TYPE	CNTFGL	CNTFGL.	RECT.	VERT CYL.	VERT CYL	DIAPH	VERT CYL.	ROTARY DRUM	VERT CYL	
ENERGY REQ	4 Kwh	4 Kwh		1 Kwh		0.5 Kwh			1 Kwh	
PRESSURE	65 PSI	25 PSI								
RATE	70 GPM	150 GPM								
HYDR. LOAD										PHANTOM
EFFECTIVE AREA								20 FT²/10 HR		
MEDIA VOLUME										
BKW PERIOD										
BKW RATE										
HYDRAULIC HP	19 HP	22 HP (758)				0.25 HP				
DETN. TIME			24 HRS	1 HR	20 DAY STORAGE		4.7 HRS		½-1 HR	
EQUIP QUANTITY	4	2	1	1	3	3	1	1	2	
OTHER DATA								OPERATES 8 HRS./DY		

NOTE.
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70-80-C-0101

THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES: 3 PLACE DECIMALS: 2 PLACE DECIMALS:

DRAWN SJ | CHECKED | APPROVED | DATE

V J CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

SURFACTANT COMPLEXING 10^5 GPD

SIZE C | DWG NO TABLE A-2a | SCALE | SHEET 5 OF 15

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

TABLE A-2 b. DATA SHEET, SURFACTANT COMPLEXING 10^6 GPD

PVUC CAT. NUMBER	9206	9207	9218	9222	9224	9225	9228	9234	9235	9243
NOMENCLATURE	PUMP PRESS.	PUMP SUMP	TANK EQUAL	NEUT. TANK	SURF. MIX TANK	FEEDER CHEMICAL	SUMP	VACUUM FILTER	TANK SURFACT	INCIN.
DIMENSIONS	3 x 4	3 x 4	120'·25'·12'	24.5D·12UH	8'·8.5'·10'		55D0·12 UH	30.0D·10.6W	21 DIA·12 DTI	
CAPACITY			250,000	42,000 GAL (25000)	4800 GAL (5000)		200,000	850 LBS/DY	42,000 GAL (25,000)	
MATERIAL	M.I	M.I	CONCRETE	COATED STEEL	STEEL	STEEL	STEEL	DRUM	STEEL	
TYPE	CNTFGL.	CNTFGL	RECT	VERT. CYL.	RECT	GRAVITY	VERT CYL	PRECOAT ROTARY	VERT CYL	
ENERGY REQ	23 Kwh	23 Kwh		10 Kwh		37 Kwh.			10 Kwh	
PRESSURE	45 PSI	45 PSI						20" Hg		
RATE	700 GPM	700 GPM				30 LBS/HR		70 GPM		
HYDR. LOAD								0.5 GPM/FT²		PHANTOM
EFFECTIVE AREA								200 FT²/EA		
MEDIA VOLUME										
BKW PERIOD										
BKW RATE										
HYDRAULIC HP	18.3 HP (19)	18.3 HP (76)				5 HP				
DETN TIME			12 HRS	60 MIN	20 DAY STORAGE		48 HRS		30-60 MIN	
EQUIP QUANTITY	5	2	2	1	3	3	1	1	2	
OTHER DATA								OPERATES 8 HRS/DY		

NOTE:
NUMBER IN PARENTHESIS IS VALUE
USED IN THE ECONOMIC PVUC MODEL

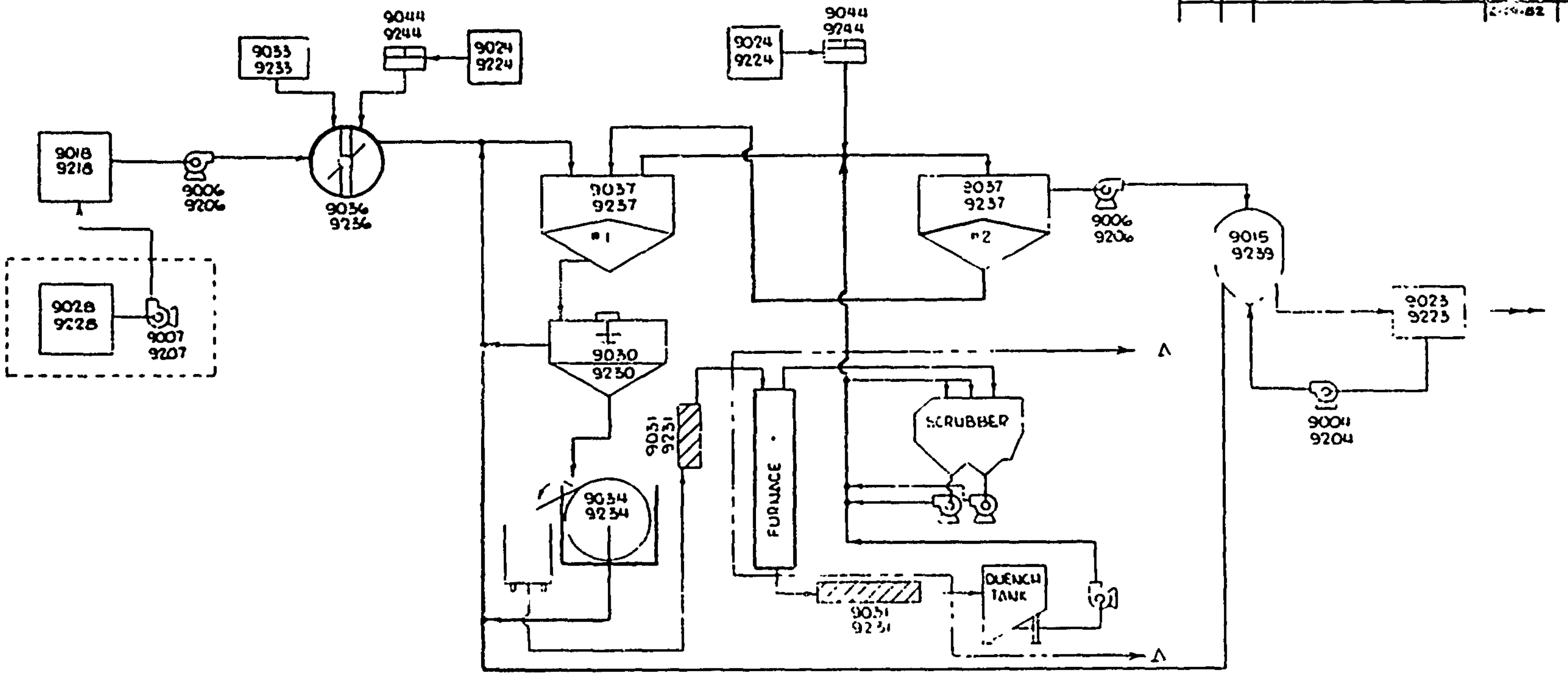
INTERPRET DRAWING IN ACCORD WITH DOD-STD-100
CONTRACT DAAK 70-80-C 0101
THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES: 3 PLACE DECIMALS: 2 PLACE DECIMALS:
DRAWN 5? 1781
CHECKED
APPROVED
DATE

V. J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

SURFACTANT COMPLEXING 10^6 GPD

SIZE C | FSCM | DWG NO. TABLE A-2b
SCALE | SHEET 6 OF 18



PVUC CAT NUMBER 10^5 GPD	PVUC CAT NUMBER 10^4 GPD	NOMENCLATURE
9004	9204	PUMP-PRESSURE BACKWASH-DE
9006	9206	PUMP-PRESSURE EQUALIZATION
9007	9207	PUMP-PRESSURE SUMP
9015	9239	FILTER-PRESSURE-DE (OR MX MEDIA)
9018	9218	EQUALIZATION SEDIMENTATION TANK
9023	9223	HOLDING TANK
9024	9224	MIX TANK
9028	9228	SUMP
9030	9230	THICKENER-GRAVITY
9031	9231	CONVEYOR-SCREW
9032	9232	AST REGENERATION SCHEME
9033	9233	POLYMER ADDITION
9034	9234	VACUUM FILTER POWDERED CARBON
9036	9236	POWDERED CARBON MIXING TANK
9037	9237	POWDERED CARBON CLARIFIER
9044	9244	DRY FEEDER

NOTE

- SECTION A-A : 9032 & 9232 (AST REGENERATION SCHEME)

FIGURE A-3, POWDERED CARBON ADSORPTION

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70-80-C-0101

THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES: 3 PLACE DECIMALS: 2 PLACE DECIMALS:

DRAWN SJ 9.13.81

V J CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

POWDERED CARBON ADSORPTION

SIZE C

FIGURE A-3

SHEET 7 OF 18

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

TABLE A-3a, DATA SHEET, POWDERED CARBON ADSORPTION 10^5 GPD

PVUC CAT NUMBER	9004	9006	9007	9015	9016	9025	9024	9028	9030	9031	9032	9033	9034	9056	9057	9044
NOMENCLATURE	PUMP BKWH	PUMP PRESS	PUMP SUMP	FILTER DE.	TANK EQUAL.	TANK HOLDING	TANK MIX	SUMP	GRAVITY THICKNER	CONVR SCREW	ATOMIZE SPRSN.	POLY ADDITION	VACUUM FILTER	TANK MIXING	CLARIFIER	FEEDER DRY
DIMENSIONS	2 x 2	2 x 2	2 x 2	25D·50H	97' 185' 8'	19 0D·120H	6 0D·30 H	18 0D 120H	60D 55'H	9'0"D 25.0'L	10D 100H		25D·25'V		8.5D 9.0H	
CAPACITY					100,000	25,000	635 GAL	25,000 GAL	1000 GAL.		2000LBS/DY		500 LBS/DAY DRY SOLIDS	100 GAL	3500 GAL.	
MATERIAL	M.I	M.I.	M.I	M.I	STEEL	STEEL	STEEL	STEEL	COATED STEEL	STEEL			M.I.		COATED STEEL	
TYPE	CNTFGL.	CNTFGL	CNTFGL	VERT CYL	RECT.	VERT CYL.	VERT. CYL.	VERT CYL.	GRAVITY			DIAPH SOLUTION	ROTARY DRUM		UP FLOW	GRAVITY
ENERGY REQ.	25 KWH	4 Kwh	4 Kwh	0.5 Kwh								2 KWH			0.7 Kwh	0.5 Kwh
PRESSURE	45 PSI	65 PSI	25 PSI	45-55 PSI					OPEN TNK			6 GPM			OPEN TNK.	
RATE	70 GPM	70 GPM	150 GPM	70 GPM	70 GPM				70 GPM						70 GPM	70 LBS/HR
HYDR. LOAD				25 GPM/FT²					0.25 GPM PER FT²						1.27 GPM PER FT²	
EFFECTIVE AREA				28 FT²					28 FT²				20 FT²/TOTAL		20 FT²	
MEDIA VOLUME				22 LBS DE/DY												
BKW. PERIOD				5 MIN												
BKW. RATE				70 GPM												
HYDRAULIC HP	1.9 HP	2.6 HP	24 HP (3.6)													
DETN. TIME					24 HRS			48 HRS	2 HRS					10 MIN	10 MIN EA	
EQUIP QUANTITY	1	3	2	2	1	1	2	1	1	2	1	1	1	1	2	2
OTHER DATA											90% EFF		OPERATES 8HS/DAY			

NOTE:
NUMBER IN PARENTHESIS IS VALUE
USED IN THE ECONOMIC PVUC MODEL

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70 80-C-0101

THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±

DRAWN SJ 11.13.81
CHECKED
APPROVED
DATE

V J CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

POWDERED CARBON ADSORPTION 10^5 GPD

SIZE C | FSCM | DWG NO TABLE A-3a
SCALE | SHEET 8 OF 15

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

TABLE A-3 b, DATA SHEET, POWDERED CARBON ADSORPTION 10^6 GPD

PVUC CAT. NUMBER	9204	9206	9207	9215	9223	9224	9228	9230	9231	9232	9233	9234	9236	9237	9239	9244
NOMENCLATURE	PUMP BKWH.	PUMP PRESS.	PUMP SUMP	TANK EQUAL	TANK HOLDING	TANK MIX	SUMP	GRAVITY THICKNER	CONVR. SCREW	ATOMIZE. SPNSN	POLY. ADDITION	VACUUM FILTER	TANK MIXING	CLARIFIER	FILTER M.B.	FEEDER DRY
DIMENSIONS	4 x 5	3 x 4	3 x 4	120'·25'·12'	19.0D·12.0H	8'·8'·10'	55.0D·12.0H	19.0D·12.0H	9.0D·25'L	7.0D 50.0H		14.0D·10.0H		71.0D·10.0H	17.5D·8.0H	
CAPACITY				250,000	25,000	4800 GAL. (5000)	200,000	25,000		2000 LBS PER DAY		830LBS/DY.	1000	35,000		
MATERIAL	M.I.	M.I.	M.I.	CONCRETE	STEEL	STEEL	STEEL	COATED STEEL	STEEL			DRUM	STEEL	COATED STEEL	STEEL	
TYPE	CNTFGL.	CNTFGL.	CNTFGL.	RECT.	VERT. CYL.	RECT.	VERT. CYL.	OPEN GRAVITY	SCREW		DIAPH. SOLUTION	PRECOAT ROTARY	VERT. CYL.	VERT. CYL.	VERT. CYL.	GRAVITY DRY
ENERGY REQ.	23 Kwh	23 Kwh	23 Kwh								2 Kwh			7 Kwh		5 Kwh
PRESSURE	25 PSI	45 PSI	45 PSI									20" Hg		OPEN TANK		
RATE	1200 GPM	700 GPM	700 GPM	350 GPM				70 GPM			6 GPM	10 GPM		700 GPM	350 GPM	70 LBS/HR
HYDR LOAD								0.25 GPM/FT²				0.5 GPM/FT²		1.27 GPM/FT²	3 GPM/FT²	
EFFECTIVE AREA								278 FT²				200 FT² EA		546 FT²	117 FT²	
MEDIA VOLUME															350 FT³	
BKW PERIOD	10 MIN.														10 MIN	
BKW RATE	15 GPM/FT²														15 GPM/FT²	
HYDRAULIC HP	18 HP (316)	18.5 HP (26)	18.5 HP (76)													
DETN TIME				12 HRS.			4.8 HRS							50 MIN		
EQUIP QUANTITY	1	3	2	2	1	2	1	1	2	1	1	1	1	2	4	2
OTHER DATA										50% EFF		OPERATES 8HRS / DY.				

NOTE.
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70-80 C 0101

THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±

DRAWN SS 11.3.81

CHECKED

APPROVED

DATE

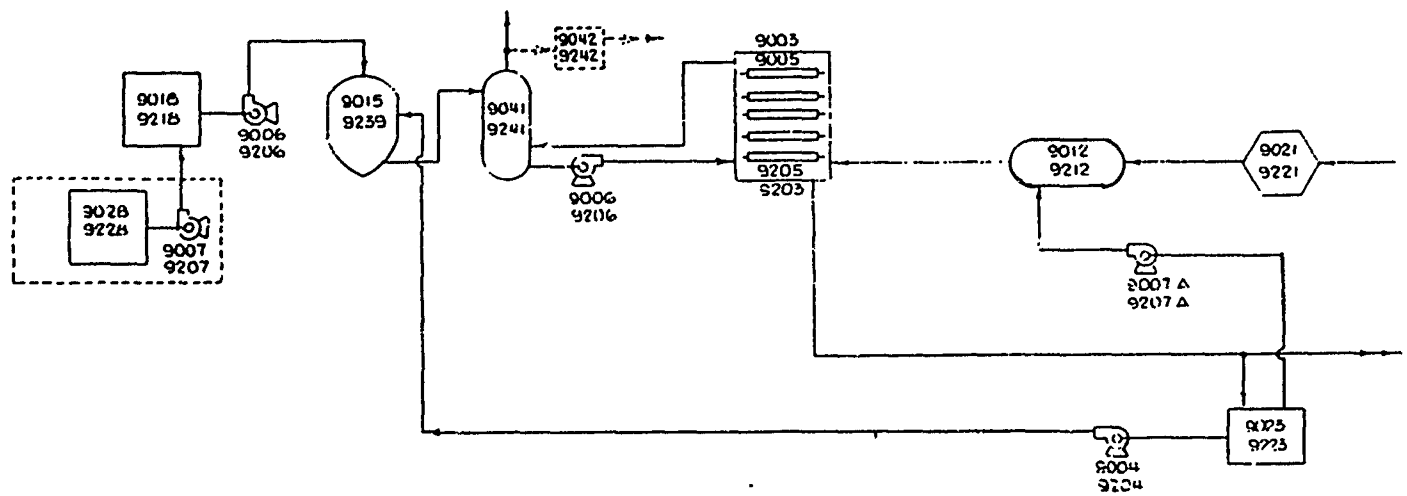
V J CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

POWDERED CARBON ADSORPTION 10^6 G.P.D

SIZE C FSCM DWG NO TABLE A-3b

SCALE SHEET 9 OF 18

DWG NO SH REV



PVUC CAT. NUMBER		NOMENCLATURE
10^3 GPD	10^4 GPD	
9003	9203	OZONE REACTOR
9004	9204	PUMP - BACKWASH DE
9005	9205	UV - LAMPS
9006	9206	PUMP - PRESSURE EQUALIZATION
9007	9207	PUMP - PRESSURE SUMP
9012	9212	OZONE GENERATOR
9015	9239	FILTER - PRESSURE - DE (OR MIX MEDIA)
9018	9218	EQUALIZATION SEDIMENTATION TNK
9021	9221	COOLER - CHILLER AIR PREPARATION
9023	9223	HOLDING TANK
9028	9228	SUMP
9041	9241	OZONE PRECONTACTOR
9042	9242	OZONE DESTROYER
9007A	9207A	PUMP - [illegible]

FIGURE A-4, UV-OZONE

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70-80-C 0101

THIS DOCUMENT IS PROPRIETARY TO V. J. CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±

DRAWN SD 9-6-81

CHECKED

APPROVED

DATE

V. J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

UV - OZONE

SIZE C

DWG NO FIGURE A-4

SCALE

SHEET 10 OF 18

					REVISIONS
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

TABLE A-4a, DATA SHEET. UV-OZONE 10^5 GPD

PVUC CAT NUMBER	9003	9004	9005	9006	9007A	9007	9012	9015	9016	9021	9023	9028	9041	9042
NOMENCLATURE	OZONE REACTOR	PUMP BKWH	UV LAMPS	PUMP PRESS	PUMP COOLING	PUMP SUMP	O_3 GEN-ERATOR	FILTER D.E	TANK EQUAL	CHILLER	TANK HOLDING	SUMP	PRECON-TACTOR	O_3 DES-TROYER
DIMENSIONS	170' 50' 240'	2 x 2	L = 5'	2 x 2	3 x 3	2 x 2	60'-80'-120'	25 D x 50 H	37' x 45' H		18 D x 170 H	10 D x 60 H	50 D x 80 H	
CAPACITY	10,700 GAL						62 LB/DY		100,000		25,700 GAL	26,000 GAL	1117 GAL	
MATERIALS	CRES	M.I	QUARTZ	M.I	M.I	M.I	CRES	COATED M.I	STEEL		STEEL	STEEL	CRES	
TYPE	6 STAGES	CNTFGL.	60 W 120V	CNTFGL.	CNTFGL.	CNTFGL.	AIR FEED	VERT CYL.	RECT	COOLER & DRIER	VERT CYL	VERT CYL	COUNTER FLOW	
ENERGY REQ.		4 Kwh	150 Kwh	4 KWH.	4 Kwh	4 Kwh	280 Kwh			140 Kwh				
PRESSURE	50 PSI	45 PSI		65 PSI	25 PSI	25 PSI	24 PSI	45-55 PSI		25 PSI			20 PSI	
RATE	70 GPM	70 GPM	65 WATTS/LAMPS	70 GPM	254 GPM	150 GPM		70 GPM		440 SCFM			70 GPM	PHANTOM
HYDR LOAD							800 MG/L	25 GPM/FT²						
EFFECTIVE AREA								2.8 FT²						
MEDIA VOLUME								22 LBS/DY						
BKW PERIOD								5 MIN						
BKW RATE								70 GPM						
HYDRAULIC HP		1.8 HP		2.6 HP (2.66)	5.4 HP (7.6)	2.2 HP (7.6)								
DETN TIME	150 MIN.								24 HRS		1 HR/CYCLE	4 HRS	10 MIN	
EQUIP QUANTITY	1	1	2304 LAMPS	3	1	2	1	2	1	1	1	1	1	
OTHER DATA			2304/TK 0 LAMPS/FT²		FOR CHILLER		630 HZ 950 V							

NOTE:
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

INTERPRET DRAWING IN ACCORD WITH DOD STD-100	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±
CONTRACT DAAK 70-80-C-0101	DRAWN SJ
THIS DOCUMENT IS PROPRIETARY TO V.J. CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.	CHECKED / APPROVED / DATE

V.J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

UV - OZONE
10^5 GPD

SIZE C | DWG NO. TABLE A-4a | SCALE | SHEET 11 OF 18

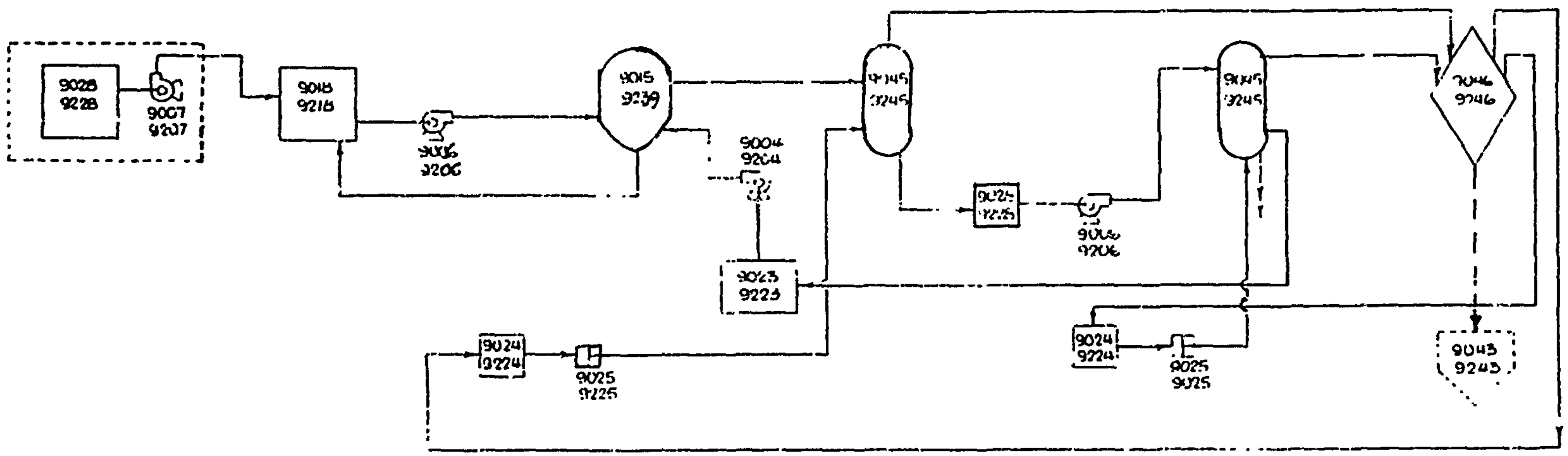
ZONE	REV	DESCRIPTION		DATE	APPROVED
				2-19-82	

TABLE A-4b, DATA SHEET, UV-OZONE 10^6 GPD

PVUC CAT NUMBER	9203	9204	9205	9206	9207A	9207	9212	9218	9221	9223	9226	9239	9241	9242
NOMENCLATURE	OZONE REACTOR	PUMP BKWH.	UV LAMPS	PUMP PRESS	PUMP COOLING	PUMP SUMP	O_3 GEN-ERATOR	TANK EQUAL	CHILLER	TANK HOLDING	SUMP	FILTER MB	PRECON-TACTOR	O_3 DES-TROYER
DIMENSIONS	40' 18' 5'	4 x 5	L = 5'	3 x 4	8 x 8	3 x 4		120 - 73 - 12'		1900 x 70 H	550 D x 70 H	15 D x 8 OH		
CAPACITY	30,000 GAL						6720 LBS PER DAY	250 000		25 000 GAL	200 000		10,000 GAL	
MATERIAL	CRES	M.I	QUARTZ	M I	M I	M I	CRES	CONCRETE	COOLER + DRIER	STEEL	STEEL	STEEL	CRES	
TYPE	6-STAGES	CNTFGL.		CNTFGL	CNTFGL.	CNTFGL.	AIR FEED	RECT.		VERT CYL.	VERT CYL	VERT. CYL.	COUNTER-FLOW	
ENERGY REQ.		25 Kwh	1497 6KVA	25 Kwh	25 Kwh	25 Kwh	2800 Kwh		1400 Kwh					
PRESSURE		25 PSI	50 PSI	45 PSI	25 PSI	45 PSI			25 PSI				50 PSI	
RATE	1751 GPM	1200 GPM	65 WATTS PER LAMP	700 GPM	2340 GPM	700 GPM		350 GPM/EA	4400 SCFM			350 GPM EA	700 GPM	
HYDR. LOAD							800 AG/L					3 GPM / FT²		
EFFECTIVE AREA												785 FT²/ FILTER		
MEDIA VOLUME												350 FT³		PHANTOM
BKW. PERIOD		10 MIN										10 MIN		
BKW. RATE		15 GPM/ FT²										15 GPM/ FT²		
HYDRAULIC HP		18 HP (31 C)		18.3 HP (2 G)	2½ HP (7 G)	18.3 HP (7 G)								
DETN. TIME	2.5 HRS							12 HRS						
EQUIP. QUANTITY	4	.	23,040 LAMPS	2	1	2	1	2	1	1	2	1	1	
OTHER DATA			5760/ TK MINN/SYS	.	FOR CHILLER		630 Hz 950 V							

NOTE:
NUMBER IN PARENTHESIS IS VALUE
USED IN THE ECONOMIC PVUC MODEL

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±	V. J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES
CONTRACT DAAK 70-80-C 0101	DRAWN SS 11 81	UV - OZONE 10^6 GPD
THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED	CHECKED	SIZE/FSCM C — DWG NO. TABLE A-4b
	APPROVED	SCALE — SHEET 12 OF 18
	DATE	



PVUC CAT. NUMBER 10^5GPD	10^6GPD	NOMENCLATURE
9004	9204	PUMP-BACKWASH FILTER
9006	9206	PUMP-PRESSURE EQUALIZATION
9007	9207	PUMP-PRESSURE SUMP
9015	9239	FILTER-PRESSURE-DE (OR MIX MEDIA)
9018	9218	EQUALIZATION SEDIMENTATION TNK.
9023	9223	HOLDING TANK
9024	9224	SOLVENT MIX TANK
9025	9225	CHEMICAL FEEDER
9028	9228	SUMP
9043	9243	INCINERATOR
9045	9245	SOLVENT EXTRACTOR
9046	9246	DISTILLATION UNIT

FIGURE A-5, LIQUID-LIQUID EXTRACTION

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100
CONTRACT DAAK 70-80-C-0101
THIS DOCUMENT IS PROPRIETARY TO V.J. CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±
DRAWN SJ 1861
CHECKED
APPROVED
DATE

V.J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES
LIQUID-LIQUID EXTRACTION
SIZE FSCM C
DWG NO. FIGURE A-5
SCALE
SHEET 13 OF 18

ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

A-5a, DATA SHEET, LIQUID-LIQUID EXTRACTION 10^5 GPD

PVUC CAT NUMBER	9004	9006	9007	9015	9018	9022	9024	9025	9026	9045	9046	9043
NOMENCLATURE	PUMP RAW	PUMP PRESS	PUMP SUMP	FILTER D.E.	TANK EQUAL	TANK HOLDING	TANK SOLVENT	FEEDER CHEMICAL	SUMP	SOLVENT EXTRACTOR	DIST UNIT	INCIN.
DIMENSIONS	2 × 2	2 × 2	2 × 2	2'0 5'0H	90' 18'5' 8'	19'0D 12'0H	5'0D 3'0H		18'0D 12'0H	3'0D 16'0H	3'0D 4'0H	
CAPACITY					100 000	25 000	500 GAL.		20,000	5675 GAL (6000)		
MATERIAL	A 1	A 1	A 1	A 1	STEEL	STEEL	STEEL		STEEL	[illegible]	SS	
TYPE	CNTFGL.	CNTFGL.	CNTFGL.	VERT CYL	RECT		VERT. CYL.	DIAPH	VERT CYL.	VERT CYL		
ENERGY REQ	4 Kwh.	4 Kwh	4 Kwh.	0.5 Kwh				0.25 HP		104 Kwh	20 Kwh	
PRESSURE	45 PSI	65 PSI	25 PSI	45 55 PSI								
RATE	70 GPM	70 GPM	150 GPM	70 GPM	70 GPM			0.7 GPM		[illegible]	10 GPM	
HYDR LOAD				2.5 GPM/FT²						[illegible] 2 DAY	[illegible] PER DAY	PHANTOM
EFFECTIVE AREA				28 FT²								
MEDIA VOLUME				22 LB DE/DAY								
BKW PERIOD				5 MIN								
BKW RATE				10 GPM								
HYDRAULIC HP	1.9 HP	2.6 HP	2.2 HP (7.6)									
DETN TIME					1 DAY		12 HRS		4.7 HRS	85 MIN		
EQUIP QUANTITY	1	3	2	2	1	1	2	2	2	2	1	
OTHER DATA												

NOTE:
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70-80-C-0101

THIS DOCUMENT IS PROPRIETARY TO V.J. CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±

DRAWN SS | CHECKED | APPROVED | DATE

V.J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

LIQUID-LIQUID EXTRACTION 10^5 GPD.

SIZE C | FSCM | DWG NO. TABLE A-5a | SCALE | SHEET 14 OF 16

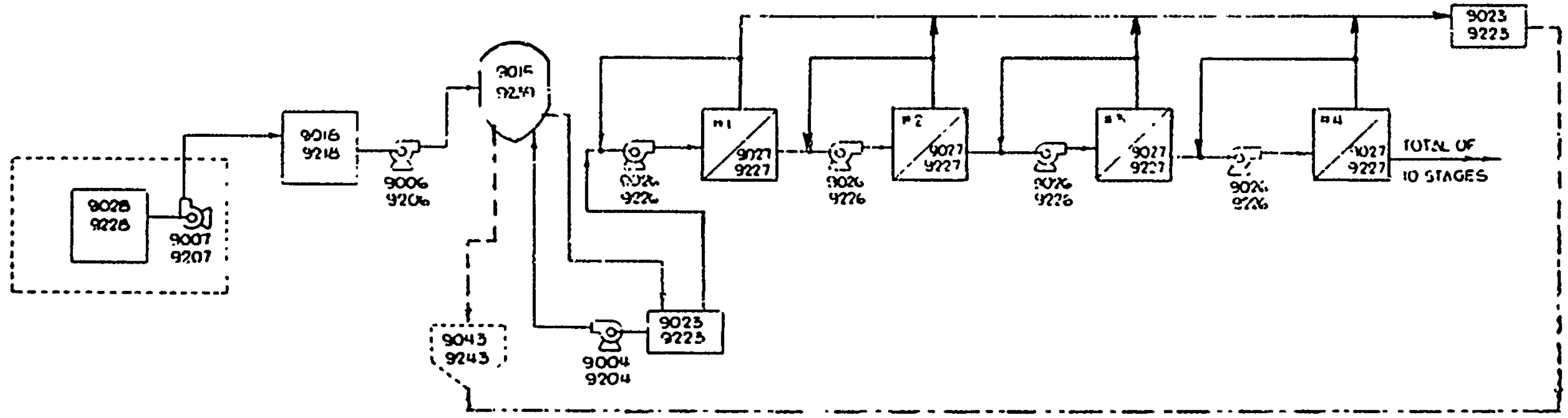
TABLE '-5 b, DATA SHEET, LIQUID-LIQUID EXTRACTION 10^6 GPD

PVUC CAT NUMBER	9204	9206	9207	9218	9223	9224	9225	9228	9239	9245	9246	9243				
NOMENCLATURE	PUMP BKWA.	PUMP PRESS.	PUMP SUMP	TANK EQUAL.	TANK HOLDING	TANK SOLVENT	FEEDER CHEMICAL	SUMP	FILTER M.B.	SOLVENT EXTRACTOR	DIST. UNIT	INCIN.				
DIMENSIONS	4×5	3×4	3×4	170'·25'·12'	13.0 D 17.0 H	4.0 D·5.0 H		55.0 D·17.0 H	12.5 D·8.0 H	28.0 D 5.0 H						
CAPACITY				250 000	25.000			200.000		30,000 EA. (60,000)						
MATERIAL	M.I.	M.I.	M.I.	CONCRETE	STEEL	STEEL	STEEL	STEEL	STEEL	FIBERGLASS	SS					
TYPE	CNTFGL.	CNTFGL.	CNTFGL.	RECT.	VERT. CYL.	VERT. CYL.	DIAPH.	VERT. CYL.	VERT. CYL.	VERT. CYL.						
ENERGY REQ.	23 Kwh.	23 Kwh.	23 Kwh.								200 Kwh.					
PRESSURE	25 PSI	45 PSI	46 PSI													
RATE	1200 GPM	700 GPM	700 GPM	350 GPM.			6 GPM		231 GPM		16.5 GPM					
HYDR LOAD									3 GPM/FT²	8,400,000 LBS/DAY	42,000 LBS/DAY	PHANTOM				
EFFECTIVE AREA									117 FT²							
MEDIA VOLUME									350 FT³							
BKW PERIOD	10 MIN.								10 MIN							
BKW. RATE	15 GPM/FT²								15 GPM/FT²							
HYDRAULIC HP	18 HP (31.6)	18.3 HP (2.6)	18.3 HP (7.6)				18.3 HP									
DETN TIME				12 HRS				9.5 HRS								
EQUIP. QUANTITY	1	8	2	2	1	2	2	2	4	4	1					
OTHER DATA																

NOTE:
NUMBER IN PARENTHESIS IS VALUE
USED IN THE ECONOMIC PVUC MODEL

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			12-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±	V. J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES
CONTRACT DAAK 70-80 C 0101	DRAWN S. 11-5-81 CHECKED APPROVED DATE	LIQUID-LIQUID EXTRACTION 10^6 GPD
THIS DOCUMENT IS PROPRIETARY TO V.J.CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED		SIZE C DWG NO. TABLE A-5 b SCALE SHEET 15 OF 15



PVUC CAT. NUMBER 10⁵GPD	PVUC CAT. NUMBER 10⁴GPD	NOMENCLATURE
9004	9204	PUMP- BACKWASH FILTER
9006	9206	PUMP-PRESSURE EQUALIZATION
9007	9207	PUMP-PRESSURE SUMP
9015	9239	FILTER PRESSURE-DE (OR MIXED)
9016	9216	EQUALIZATION SEDIMENTATION TNK.
9023	9223	HOLDING TANK
9026	9226	UF RECIRCULATION PUMP
9027	9227	UF MEM MODULE
9028	9228	SUMP
9043	9243	INCINERATOR

FIGURE A-6, ULTRA-FILTRATION

REVISIONS: DATE 2-19-82

CONTRACT DAAK 70 80 C 0101

V. A. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

ULTRA-FILTRATION

SIZE C — DWG NO. FIGURE A-6 — SHEET 16 OF 15

TABLE A-6a, DATA SHEET, ULTRA-FILTRATION 10^5 GPD

PVUC CAT. NUMBER	9004	9006	9007	9015	9018	9025	9026	9027	9028	9043
NOMENCLATURE	PUMP BKWH	PUMP PRESS	PUMP SUMP	FILTER UF	TANK EQUAL	TANK HOLDING	PUMP UF RECIR	UF MEM. MODULES	SUMP	INCIN.
DIMENSIONS	2×2	2×2	2×2	250 50'H	30' 105' 8	19'D 17'H	4×6'	12·3'·4' PER STAGE	11'D 17'H	
CAPACITY					100,000	25,000			10,000 GAL	
MATERIAL	A.I	A.I	A.I	A.I	STEEL	STEEL	A.I	POLY SULFONE	STEEL	
TYPE	CNTFGL.	CNTFGL.	CNTFGL.	VERT CYL	RECT		VERT AXIAL	HOLLOW FIBERS	VERT CYL	
ENERGY REQ	4 Kwh	4 Kwh	4 Kwh	0.5 Kwh			64 Kwh			
PRESSURE	45 PSI	45 PSI	25 PSI	15-55 PSI			30 PSI	75 PSI		
RATE	70 GPM	70 GPM	150 GPM	70 GPM	70 GPM		5000 GPM	46 GPM/MODULE		
HYDR LOAD				25 GPM/FT²						PHANTOM
EFFECTIVE AREA				28 FT²				26.5 SQ FT/MODULE		
MEDIA VOLUME				27.85 CU/FT						
BKW PERIOD				5 MIN				CHEMICAL CLEANING		
BKW RATE				70 GPM						
HYDRAULIC HP	1.9 HP (2G)	1.9 HP (2G)	2.2 HP (7G)				50.4 HP			
DETN TIME					24 HRS	6 HRS			11.8 HRS	
EQUIP QUANTITY	1	2	2	2	1	2	10	10 STAGES	1	
OTHER DATA								145 MOD/STAGE		

NOTE:
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70 80 C-0101

THIS DOCUMENT IS PROPRIETARY TO V.J. CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±

DRAWN SJ · CHECKED · APPROVED · DATE

V.J. CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

ULTRA - FILTRATION 10^5 GPD

SIZE C · DWG NO. TABLE A-6a · SCALE · SHEET 17 OF 18

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
			2-19-82	

TABLE A-6b, DATA SHEET, ULTRA-FILTRATION 10⁶ GPD

PVUC CAT NUMBER	9204	9206	9207	9218	9225	9226	9227	9228	9259	9243
NOMENCLATURE	PUMP BKWH	PUMP PRESS	PUMP SUMP	TANK EQUAL	TANK HOLDING	PUMP UF RECIR.	UF AREA MODULES	SUMP	FILTER MB	INCIN
DIMENSIONS	4 x 5	3 x 4	3 x 4	120·25·12	140 D 120 H	4 x 6	7' C · 4'	55 D 20 H	12 5 D 8 0 H	
CAPACITY				250,000	25,000		14,500 MODULES	200,000		
MATERIAL	M I	M I.	M I	CONCRETE	STEEL	M.I		STEEL	STEEL	
TYPE	CNTFGL	CNTFGL.	CNTFGL.	RECT.	VERT CYL.	VERT AXIAL	HOLLOW FIBERS	VERT CYL	VERT CYL	
ENERGY REQ	23 Kwh	25Kwh	25Kwh			64 Kwh				
PRESSURE	25 PSI	45 PSI	45 PSI			30 PSI	25 PSI			
RATE	1200 GPM	700 GPM	700 GPM	350 GPM		3000 GPM	.46 GPM/ MODULE		350 GPM	
HYDR LOAD							26.5 FT²/ MODULE		3 GPM/FT²	
EFFECTIVE AREA							384,250 FT²		117 FT²	PHANTOM
MEDIA VOLUME									350 FT³	
BKW PERIOD	10 MIN						CHEMICAL CLEANING		10 MIN	
BKW RATE	15 GPM/FT²								5 GPM/FT²	
HYDRAULIC HP	16 HP (3.6)	10.5 HP (2.6)	10.5 HP (7.6)			50.4 HP				
DETN TIME				12 HRS				4.8 HRS		
EQUIP QUANTITY	1	2	2	2	1	100	100 STAGES	1	4	
OTHER DATA							145 MOD PER BANK			

NOTE
NUMBER IN PARENTHESIS IS VALUE USED IN THE ECONOMIC PVUC MODEL

INTERPRET DRAWING IN ACCORD WITH DOD-STD-100

CONTRACT DAAK 70-80-C-0101

THIS DOCUMENT IS PROPRIETARY TO V J CICCONE & ASSOCIATES, INC. AND SHALL NOT BE REPRODUCED OR USED IN ANY FORM, NOR DISCLOSED TO OTHERS, EXCEPT WHERE OTHERWISE AUTHORIZED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ±

DRAWN SS 11581
CHECKED
APPROVED
DATE

V J CICCONE & ASSOCIATES, INC. ENGINEERING SERVICES

ULTRA - FILTRATION 10⁶ GPD

SIZE C FSCM DWG NO TABLE A-6b
SCALE SHEET 18 OF 18

DWG NO SH REV

APPENDIX B

DATA SET FOR PVUC ANALYSES INVOLVING FLOW RATES OF 100 000 GPD

```
*************************************************************************************
 THE TITLE OF EACH UNIT IS GIVEN FOLLOWED BY:

 CAT   CAPACITY GALLONS  UNIT CAPITAL                 O & M
 NUM    IN GAL  PER DAY  COST FUNCTION                FUNCTION
        OR NUM  SEEN BY
      OF UNITS   UNIT
-------------------------------------------------------------------------------------
OZONE REACTOR
 9003    10000    100000  326000                      0

PUMP-PRESS. BACKWASH-D.E.
 9004    1.89     10000   636*G1**.51                 3.76*(G1**.62)*.25*.33*D9*.03

UV LAMPS
 9005    2304     100000  1                           ((1.25*G1)*50+G1*.095*24*.035*D9)

PUMP-PRESS. EQUALIZATION
 9006    2.66     100000  636*G1**.51                 3.76*(G1**.62)*24*D9*.03

PUMP-PRESS. SUMP
 9007    7.58     100000  636*G1**.51                 3.76*(G1**.62)*24*D9*.03

VIRGIN CARBON STORAGE TANK
 9008    24000    24000   74.5*G1**.46                0

CARBON WASH TNK -STL OR MI
 9009    3000     5000    88.4*G1**.44                0

QUENCH TANK -STL OR MI
 9010    5000     1000    13E3+.27*G2                 1E3

CARBON REGEN FURNACE
 9011    1        30      133745*G2**.404             2500*G2**.715

OZONE GENERATOR
 9012    1        100000  148113*E9**(.78E-6*G2)      8064*.035*D9

CARBON COLUMN-GRANULAR
 9013    2000     100000  137513*(E9**(96E-8*G2))     4.32E4*E9**(2.2E-6*G2)+27E3

WASTE CARBON TNK-STL OR MI
 9014    12000    1000    88.4*G1**.44                0
```

CAT NUM	CAPACITY IN GAL OR NUM OF UNITS	GALLONS PER DAY SEEN BY UNIT	UNIT CAPITAL COST FUNCTION	O & M FUNCTION
FILTER-PRESSURE-DE				
9015	200	50000	307466*((G2*1E-6)©.6[illegible]	844*E9©(1.2E-6*G2)
EQUALIZATION TNK-CONC.				
9016	.1	.1	279105*E9©(.49*G1)	276*E9©(.6*G2)
EQUALIZATION TNK-EARTHEN				
9017	.1	.1	197432*(G1©.41)	0
EQUALIZATION/SEDIMENTATION TANK -STL				
9018	100000	25000	29.76*G1©.56	0
CARBON COLUMN WITH THERMAL REGEN.				
9019	2000	100000	137513*(E9©(96E-8*G2))	5.8E3*E9©(2.2E-6*G2)
SCRUBBER				
9020	100	.1	2*(8547+489*G1-1.02*G1©2)	.35*G2
COOLER-CHILLER				
9021	1	1	5000	2000
NEUTRALIZATION TANK				
9022	5000	100000	88.4*G1©.44	(450*D9*.50)+2E3
HOLDING TANK				
9023	25000	100000	88.4*G1©.44	0
SURF. STR/MIX/BODY FEED TNK				
9024	500	0	88.4*G1©.44	0
CHEMICAL FEEDER				
9025	1	1	3E3	1E3
UF-RECIRC. PUMP				
9026	75.6	4320000	636*G1©.51	3.76*(G1©.62)*24*D9*.03
UF MEMBRANE MODULE				
9027	.1	.1	7080991*G1©.67	796011*G1©.56
SUMP-STL OR MI				
9028	20000	100000	88.4*G1©.44	0

CAT NUM	CAPACITY IN GAL OR NUM OF UNITS	GALLONS PER DAY SEEN BY UNIT	UNIT CAPITAL COST FUNCTION	O & M FUNCTION
CLARIFIER-CIRCULAR				
9029	6000	100000	1083E2*(G2*1E-6)©.45	6550*(G2*1E-6)©.474
THICKENER-GRAVITY				
9030	2000	10000	2654E2*(G2*1E-6)©.52	3E4*(G2*1E-6)©.44
CONVEYOR SCREW				
9031	1	25	2*(633+66*G2)	1E3
AST-FURNACE (250 LB/DAY)				
9032	1	100000	2*(67E3)	24E3
POLYMER ADDITION				
9033	500	100000	68E2*E9©(G2*1E-6)	7E3*E9©(G2*.95E-6)
VACUUM FILTER POWDERED CARB.				
9034	1	20	128E2*(G2©.584)	((50*G2©.73)+(60*G2©.70)+(66*G2©.88))
SURFACT REACT TANK				
9035	5000	100000	(88.4*G1©.44)+2E3	(60*D9*1.00)+2E3
POWD. CARB. MIX TANK				
9036	100	100000	88.4*G1©.44	1E3
POWD. CARB. CLARIFIER				
9037	5000	100000	247E3*((G2*1E-6)©.31)	(26E4*((G2*1E-6)©.58))-(183*D9*.60)
VACUUM FILTER-SURFACTANTS				
9038	1	278	128E2*(G2©.584)	150*G2©.88+250*D9*.15
CARBON DE-FINE TANK				
9040	2500	2500	137513*(E9©(96E-8*G2))	1E3
OZONE PRECONTACTOR				
9041	1000	100000	88.4*G1©.44	0
OZONE DESTROYER				
9042	1	1	1	0

CAT NUM	CAPACITY IN GAL OR NUM OF UNITS	GALLONS PER DAY SEEN BY UNIT	UNIT CAPITAL COST FUNCTION	O & M FUNCTION
DRY FEEDER				
9044	100000	100000	3.75E4-88.4*G1©.44	2.1E4
SOLVENT EXTRACTION				
9045	6000	.84	1.2E6*G2©.7	8[illegible]2©.59
FRACTIONAL DISTILLATION				
9046	1.29	1000000	403140*G1©.703	78142*G1©.658
DUMMY				
9058	1	1	1	1

NOTES: D9 = number of operating days

E9 = function e

1En = 10^n

© = power function, i.e., raised to the number that follows

APPENDIX C

DATA SET FOR PVUC ANALYSES INVOLVING FLOW RATES OF 1 000 000 GPD

****

THE TITLE OF EACH UNIT IS GIVEN AND FOLLOWED BY:

CAT NUM	CAPACITY IN GAL OR NUM OF UNITS	GALLONS PER DAY SEEN BY UNIT	UNIT CAPITAL COST FUNCTION	O & M FUNCTION
OZONE REACTOR				
9203	30000	1000000	2*326000	0
PUMP-PRESS. BACKWASH				
9204	31.6	100000	636*G1©.51	3.76*(G1©.62)*.25*D9*.03
UV LAMPS/REACTOR TANK				
9205	5760	1000000	1	((1.25*G1)*50+G1*.095*24*.035*D9)
PUMP-PRESS. EQUALIZATION				
9206	2.66	1000000	636*G1©.51	3.76*(G1©.62)*24*D9*.03
PUMP-PRESS. SUMP				
9207	7.58	1000000	636*G1©.51	3.76*(G1©.62)*24*D9*.03
VIRGIN CARBON STORAGE TANK				
9208	24000	24000	74.5*G1©.46	0
CARBON WASH TNK -STL OR MI				
9209	30000	50000	88.4*G1©.44	0
QUENCH TANK -STL OR MI				
9210	25000	10000	13E3+.27*G2	1E3
CARBON REGEN FURNACE				
9211	1	300	133745*G2©.404	2500*G2©.715
OZONE GENERATOR				
9212	1	1000000	148113*E9©(.78E-6*G2)	60360*.035*D9
CARBON COLUMN-GRANULAR				
9213	21000	1000000	137513*(E9©(96E-8*G2))	53E3*E9©(2.2E-6*G2)+27E4
WASTE CARBON TNK-STL OR MI				
9214	25000	10000	88.4*G1©.44	0

CAT NUM	CAPACITY IN GAL OR NUM OF UNITS	GALLONS PER DAY SEEN BY UNIT	UNIT CAPITAL COST FUNCTION	O & M FUNCTION
FILTER-PRESSURE-D.E.				
9215	2000	340000	307466*((G2*1E-6)©.65)	844*E9©(1.2E-6*G2)
EQUALIZATION TNK-CONC.				
9216	.1	.1	279105*E9©(.49*G1)	276*E9©(.6*G2)
EQUALIZATION TNK-EARTHEN				
9217	.1	.1	197432*(G1©.41)	0
EQUALIZATION/SEDIMENTATION TANK-STL				
9218	1000000	1000000	29.76*G1©.56	0
CARBON COLUMN WITH THERMAL REGEN.				
9219	21000	1000000	137513*(E9©(96E-8*G2))	5.3E3*E9©(2.2E-6*G2)
SCRUBBER				
9220	100	.1	2*(8547+489*G1-1.02*G1©2)	.35*G2
COOLER-CHILLER				
9221	1	1	5000	2000
NEUTRALIZATION TANK				
9222	25000	1000000	(88.4*G1©.44)+2E3	(4500*D9*.50)+2E3
HOLDING TANK				
9223	25000	1000000	88.4*G1©.44	0
SURF. STR/MIX/BODY FEED TNK				
9224	500	0	88.4*G1©.44	0
CHEMICAL FEEDER				
9225	1	1	3E3,	1E3"
UF-RECIRC. PUMP				
9226	75.6	4320000	636*G1©.51	3.76*(G1©.62)*24*D9*.03
UF MEMBRANE MODULE				
9227	.1	.1	7080991*G1©.67	795011*G1©.56
SUMP-STL OR MI				
9228	200000	1000000	88.4*G1©.44	0

CAT NUM	CAPACITY IN GAL OR NUM OF UNITS	GALLONS PER DAY SEEN BY UNIT	UNIT CAPITAL COST FUNCTION	O & M FUNCTION
CLARIFIER-CIRCULAR				
9229	6000	1000000	1083E2*(G2*1E-6)©.445	6550*(G2*E1-6)©.474
THICKNER-GRAVITY				
9230	[illegible]	[illegible]	[illegible] 2*1E-6)©.52	3E4*(G2*1E-6)©.44
CONVEYOR SCREW				
9231	1	25	2*(633+66*G2)	2E3
AST-FURNACE (250 LB/DAY)				
9232	1	1000000	1.5E6	238E3
POLYMER ADDITION				
9233	500	1000000	68E2*E9©(G2*1E-6)	7E3*E9©(G2*.95E-6)
VACUUM FILTER POWDERED CARB.				
9234	1	200	128E2*(G2©.584)	(50*G2©.73)+(60*G2©.70)+(66*G2©.88)
SURFACT REACT TANK				
9235	25000	1000000	(88.4*G1©.44)+2E3	(750*D9*1.00)+2E3
POWD. CARB. MIX TANK				
9236	1000	1000000	88.4*G1©.44	3E3
POWD. CARB. CLARIFIER				
9237	36000	1000000	247E3*(G2*1E-6)©.31	(26E4*(G2*1E-6)©.58)-(183*D9*.60)
VACUUM FILTER-SURFACTANTS				
9238	1	468	128E2*(G2©.584)	150*G2©.88+250*D9*.15
MIXED MEDIA PRESS. FILT.				
9239	5000	340000	77575*E9©(1.12*G2*1E-6)	269*E9©(.82*G2*1E-6)+77*E9©(.91*G2*1E-6)
CARBON DE-FINE TANK				
9240	25000	25000	137513*(E9©(96E-8*G2))	2E3
OZONE PRECONTACTOR				
9241	10000	1000000	88.4*G1©.44	0
OZONE DESTROYER				
9242	1	1	1	0

CAT NUM	CAPACITY IN GAL OR NUM OF UNITS	GALLONS PER DAY SEEN BY UNIT	UNIT CAPITAL COST FUNCTION	O & M FUNCTION
DRY FEEDER				
9244	1000000	1000000	7.5E4-88.4*G1©.44	1.23E5
SOLVENT EXTRACTION				
9245	60000	8.4	1.2E6*G2©.7	86E4*G2©.59
FRACTIONAL DISTILLATION				
9246	12.9	1000000	403140*G1©.703	78142*G1©.658
DUMMY				
9250	1	1	1	1

NOTES: D9 = number of operating days

E9 = function e

1En = 10^n

© = power function, i.e., raised to the number that follows

DISTRIBUTION LIST

Addressee	Number of Copies
Defense Technical Information Center Cameron Station Alexandria, VA 22314	12
Defense Logistics Studies Information Exchange U.S. Army Logistics Management Center Fort Lee, VA 23801	2
Commander U.S. Army Toxic and Hazardous Materials Agency ATTN: DRXTH-ES Aberdeen Proving Ground, MD 21010	2
Commander U.S. Army Toxic and Hazardous Materials Agency ATTN: DRXTH-TE-D Aberdeen Proving Ground, MD 21010	6
Commander U.S. Army Armament Research and Development Command ATTN: DRDAR-LCE-C Dover, NJ 07801	1
Commander Tooele Army Depot ATTN: SDSTE-AEO Tooele, UT 84074	1
Commander U.S. Army Environmental Hygiene Agency ATTN: HSE-EW Aberdeen Proving Ground, MD 21010	1
Commander U.S. Army Mobility Equipment Research and Development Command ATTN: DRDME-PEA Fort Belvoir, VA 22060	1

Addressee	Number of Copies
Commander U.S. Army Mobility Equipment Research and Development Command ATTN: DRDME-GS Fort Belvoir, VA 22060	2
Commander U.S. Army Material Development and Readiness Command ATTN: DRCIS-A 5001 Eisenhower Avenue Alexandria, VA 22333	1
Commander DARCOM Installations and Services Activity ATTN: DRCIS-RI-U Rock Island, IL 61299	1
Commander U.S. Army Munitions Production Base Modernization Agency ATTN: SARPM-PBM-EC (Mr. Wong) Dover, NJ 07801	1
Commander U.S. Army Armament Material Readiness Command ATTN: DRSAR-ISE Rock Island, IL 61299	1
Commander U.S. Army Armament Material Readiness Command ATTN: DRSAR-IRC Rock Island, IL 61299	1
Commander U.S. Army Depot System Command ATTN: DRSDS-EF Chambersburg, PA 17201	1
Commander U.S. Army Armament Research and Development Command ATTN: DRDAR-LCM-SA Dover, NJ 07801	1